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TECHNICAL REPORT 46

CALIBRATION OF SPRAY SYSTEMS
C-123/MC-1
H-34/HIDAL
A-1H/FIDAL

Sponsored by

Advanced Research Projects Agency
Project Agile
ARPA Order 256

JUNE 1964

UNITED STATES ARMY
BIOLOGICAL LABORATORIES
FORT DETRICK

U.S. ARMY BIOLOGICAL LABORATORIES
Fort Detrick, Frederick, Maryland

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CALIBRATION OF SPRAY SYSTEMS
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This research was supported by the Advanced Research Projects Agency Project Agile under ARPA Order 256.

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Project ARPA Order 256

June 1964

ABSTRACT

The Advanced Research Projects Agency of the Office of the Secretary of Defense sponsored the calibration trials of two aerial spray systems. These trials were conducted from May through July 1963 at Eglin Air Force Base, Florida, and were essentially an extension of trials in July 1962, but with altered systems.

The first system, the C-123/MC-1, was rigged primarily as a research system in order to obtain a variety of configurations such that the most practical could be indicated. The second system, the H-34/HIDAL, differed from the original model calibrated in July of 1962 at Eglin Air Force Base in that its flow rate approached 70 gallons per minute, almost three times the flow rate of the original system.

A new concept called FIDAL was tested for possible use with A-1E and/or A-1H aircraft and is reported in Supplement III.

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I. INTRODUCTION

A. BACKGROUND

The calibration data reported here were obtained in the extension of previous work[1,2] on two systems, the C-123/MC-1 and the H-34/HIDAL (Helicopter Insecticide Dispersal Apparatus, Liquid). The former consisted of a 1000-gallon aluminum tank, a ten-horsepower gasoline engine and pump combination, and wing booms; these were all mounted in and on a C-123 aircraft. At the maximum flow rate of about 200 gallons per minute, this system could provide a spray of Purple code material at a deposit rate of 1½ gallons per acre over a 300-foot swath. The mass median diameter (MMD) of the droplets was about 300 microns when the spray was released inwind, or nearly so, from 150 feet above terrain at an indicated airspeed of 130 knots (150 miles per hour). This provided a spray of relatively large droplets for increased aimability and a deposit of three gallons per acre for increased assurance of effect. Both of these parameters were recommended by others, and this level of deposit was obtained operationally only by two separate spray passes over the same area.[3-6] This procedure contributes to better coverage of the area sprayed, but has the disadvantage of extending the time of the aircraft's exposure to possible enemy fire, expecially where the two passes are made on the same mission by a single aircraft.

The data in this report concern the performance of different configurations or modifications of the two aerial spray systems mentioned above. The A-1H/FIDAL concept is reported in Supplement III.

A C-123*/MC-1 system was specially rigged for selected variability of spray delivery, primarily in terms of greater flow rate (in order to obtain a deposit of three gallons per acre or more) and with the addition of a tail boom (Figure 1). Its configuration, therefore, should be considered that of a research vehicle and not necessarily as a separate modification or as a prototype

The standard HIDAL consists of a 200-gallon fiber glass tank, an electric motor and positive displacement pump combination, and two stainless steel booms mounted one on each side of the helicopter fuselage. The standard HIDAL, installed in an H-34 and spraying Purple code material at 24 gallons per minute, provided essentially a 100- to 150-foot swath at a deposit rate of one gallon per acre, with a particle MMD of about 350 microns on inwind releases from a height of 75 feet and at an indicated airspeed of 50 knots (57.6 miles per hour).

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* Aircraft number 56-4386.

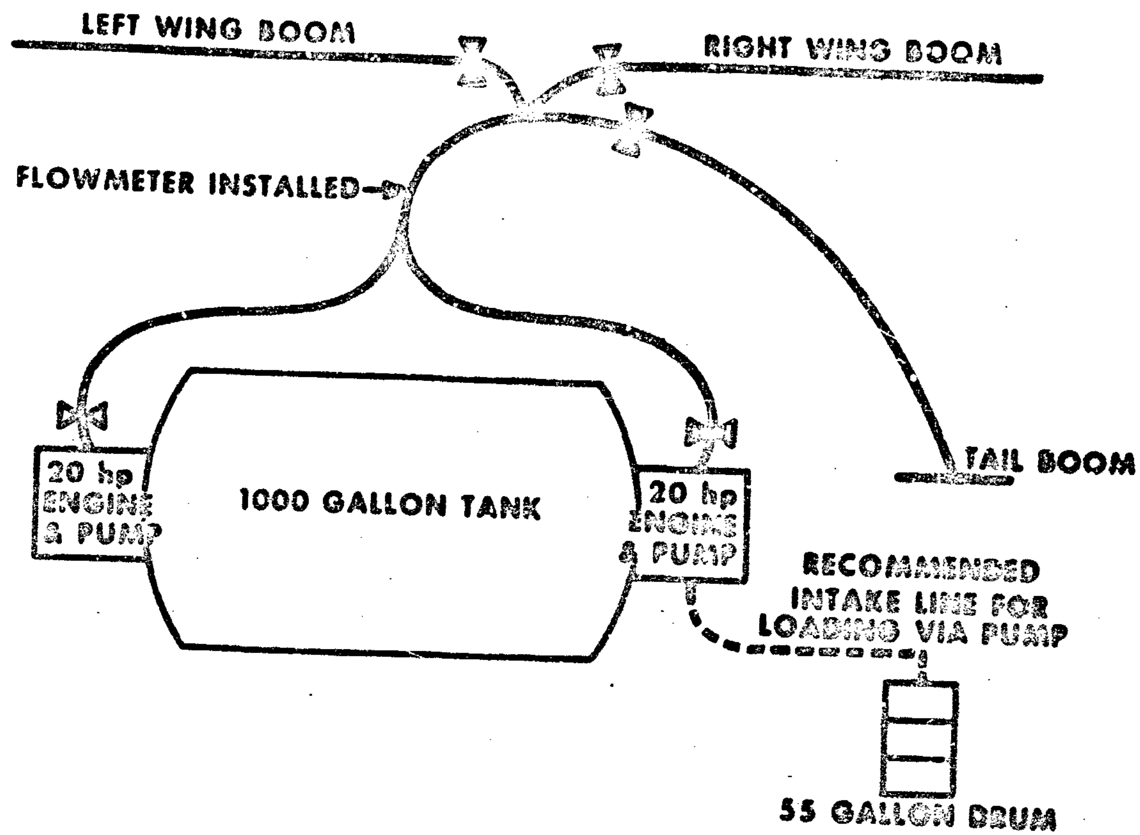


Figure 1. Diagram of Dissemination System of C-123/MC-1.

The HIDAL was first used OCONUS[a,7] in August 1961 to spray herbicidal materials, and minor modifications were made to the system that subsequently indicated the possibility of using greater airspeeds for the delivery of spray release or flow rate by the system.[2] The data presented here concern a modified HIDAL system (Figure 2) that can provide a flow rate of 65 to 70 gallons per minute of Purple code material.

B. APPROACH

The questions below were considered in planning the 1963 calibration trials at Eglin Air Force Base.

1. What effective swath widths could be obtained for each of the systems and for functioning parts of the C-123/MC-1 system under the following conditions?

(a) At different flow rates for the MC-1,

(b) At different altitudes for HIDAL,

(c) At different airspeeds for HIDAL,

(d) Using a variety of nozzles for HIDAL,

(e) Using different liquid fills.

2. What spray deposit characteristics could be obtained with these systems?

(a) Mass median diameters for various conditions above,

(b) Plots of deposit of selected flights.

3. What percentage of the various materials sprayed by these systems could be recovered as measurable ground deposit?

Appendix E presents some details of the preliminary planning for these tests.

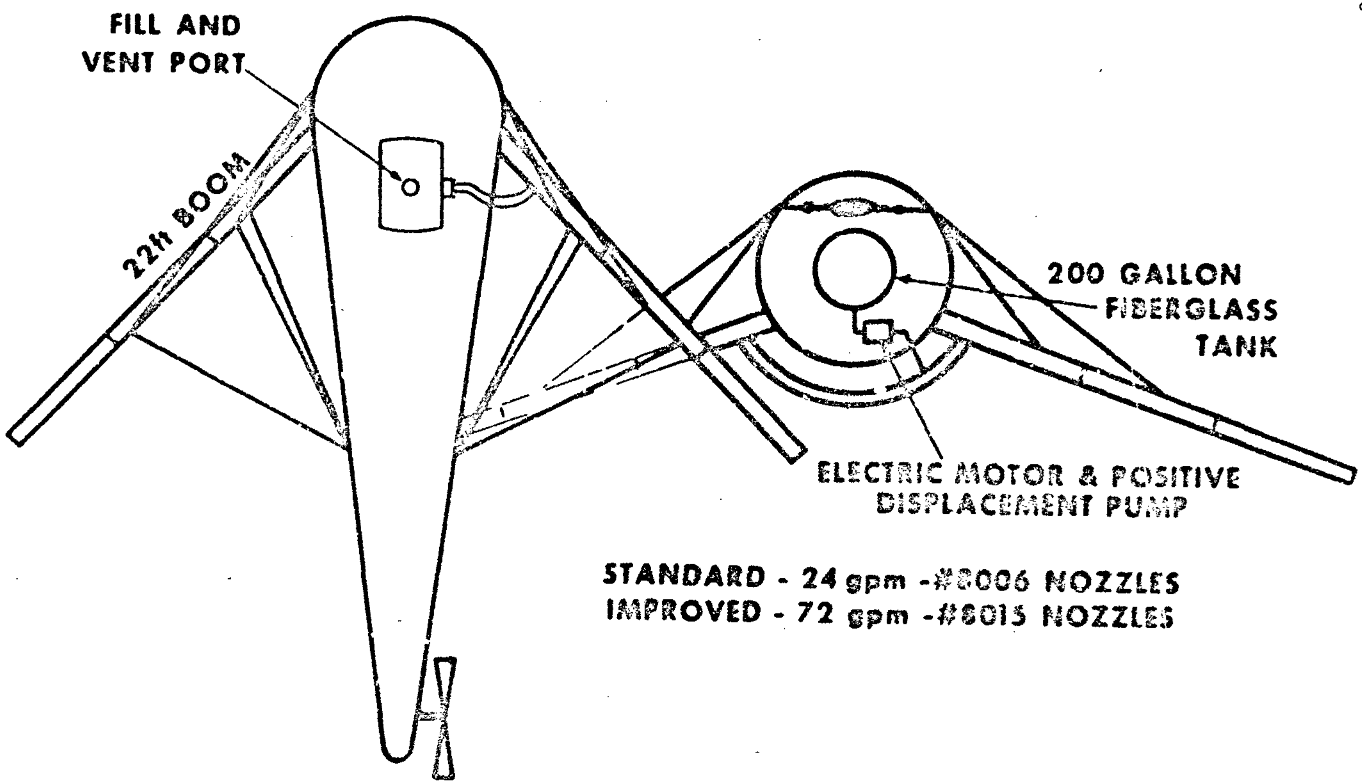


Figure 2. Diagram of Dissemination System of H-34/HIDAL.

II. METHODS

The aerial spray equipment was flown over the spray sampling grid established for this purpose the previous year[1,2] at Eglin Air Force Base. Because a capability for aiming the spray is desired, flights were made inwind to obtain mass deposit information and related effective swath widths. Crosswind flights were flown intentionally for the primary purpose of obtaining information on mass median diameter. The method for this droplet size determination has been described elsewhere[1] and calls for finding the largest qualifying droplet. On crosswind spray flights the smaller droplets are carried farther downwind than large droplets. This separation makes it much simpler to find the single largest qualifying droplet.

For all mass deposit test information, Du Pont Oil Red Dye was used in known concentrations in the liquid sprays. After spray releases, metal sample plates (6 by 6 inches) were collected after an interval of ten minutes that allowed the spray to settle. They were kept in serial order in light-tight boxes until they were delivered to the laboratory, where they were separately washed with acetone; the washings were then collected in a volumetric flask and brought to volume. The density of dye was measured spectrophotometrically and converted into gallons per acre deposited per sampling station. Appendix F contains details of methods and techniques for these trials.

All "inwind" flights were directed over the sampling grid at right angles to the sampling line most nearly normal to the prevailing wind direction. After the mass deposit curves had been drawn, it was possible to select and examine the data of those flights that were most nearly inwind (Appendix A).

III. DISCUSSION

A. DISPERSION PROBLEMS

Where MMD's of delivered spray are 300 microns or larger and the spray is released inwind under inversion conditions, the large droplets are deposited first and most directly beneath the flight line of the aircraft. Smaller droplets tend to be dispersed laterally to a greater distance. Thus, where wing booms only are operated on attempted inwind flights with the C-123, there is a minimal altitude below which the released sprays do not merge beneath the fuselage prior to deposit, at least not in biologically meaningful quantities.

Depending on the type of aircraft (heavy or light, single or multi-engine, fixed or rotary wing) and the air turbulence caused by its passage through the air, a spray released near or under its fuselage may be heavily deposited directly downward with relatively little lateral displacement, particularly under relatively still atmospheric conditions.

Efforts were made in the 1962 trials to prevent undue influence on the distribution of spray deposit by the turbulence caused by the wingtip vortices of the aircraft. However, aerial photography in these calibration trials revealed classical examples of the major effect of these vortices even though the same nozzle placement was used. It is concluded that under the conditions of spray release obtained, particularly in regard to the altitude, airspeed, weight, spray boom configurations, wingspan, and aerodynamics of the spray aircraft, the influence of the wingtip vortices plays a major part in the lateral distribution of spray deposit and should be exploited instead of attempting to cancel or avoid its effect on inwind flights.

Where the peaking of spray deposit is quite high, it may be desirable in practice to use landing flaps on the C-123 while spraying to create greater air turbulence and so reduce the peaks of spray deposit. Under these conditions, care should be taken not to contaminate the aircraft; the degree of use of the flaps should be adjusted accordingly. Another possibility would be to fly two planes in line so that a non-spraying plane would create air turbulence for the spray released by a plane following slightly above and some distance behind it.

Most information on aerial sprays for agricultural purposes reported in the literature pertains to insect or plant disease control. Principles developed for these purposes, in many instances planned for direct benefit to the farmer, do not necessarily apply to the use of various military aircraft usually operating at greater altitudes and airspeeds. For example, an altitude for military spraying is not likely to be less than 50 feet and may be 1½ to 3 or more times this height, whereas for many agricultural

purposes a 50-foot altitude is, under most circumstances, an upper limit. Exceptions can be cited, of course, but in general the foregoing applies. For agricultural applications altitudes of one to ten feet above a crop are not uncommon.

An aerial system considered most efficient for releasing liquid spray for a deposit of 1½ gallons per acre is not necessarily the most efficient for a release to obtain a deposit of three gallons per acre. Using a system that provides 1½ gallons per acre and spraying the same area twice will provide better coverage for biological purposes. However, military requirements may indicate a single pass as essential.

Alternatives available include:

(a) Spraying the area in one pass with one aircraft at three gallons per acre.

(b) Spraying the area in one pass with two aircraft, each spraying 1½ gallons per acre.

(c) Spraying the area once at 1½ gallons per acre and repeating the spray after an interval of four to six weeks if necessary, thus allowing the first spray to reach maximum effectiveness.

B. PER CENT RECOVERY

For all selected flights, the percentage of spray recovered as deposit was calculated by the formula:

$$\text{per cent recovery} = \frac{0.202 \times S \times D \times I}{F}$$

where:

0.00202 is a constant representing the portion of an acre covered in 1 minute at 1 mph with a swath width of 1 foot. Multiplied by 100 to convert to percentage, the constant becomes 0.202.

S = speed of aircraft in miles per hour

D = total deposit collected on sample line in terms of gallons per acre

I = interval of sample stations in feet

F = flow rate of spray in gallons per minute

This formula can be developed as follows:

$$\text{per cent recovery} = \left(\frac{\text{Amount recovered in 0.5-ft strip}}{\text{Amount delivered in 0.5-ft strip}}\right) 100$$

1. Amount Recovered in 0.5-Foot Strip

The proportion of an acre represented on a sample card =

$$\frac{\text{sq. ft. on card}}{\text{sq. ft. in acre}} = \frac{0.25}{43{,}560}$$

Amount, in gallons, on a given sample card =

$$\left(\frac{0.25}{43{,}560}\right) \left(gpa_i\right)$$

where gpa_i = gallons per acre estimated from i-th card

Assume that:

(a) The i-th sample card represents the midpoint of an area, (b) A uniform deposit is obtained over this area.

Then the estimated gallons in a section of a 0.5-foot strip represented by the i-th sample card is the ratio of the area (0.5 ft x I) to the square feet in the sample card multiplied by the amount deposited on the i-th card, or

$$\left(\frac{0.5 \text{ ft} \times I}{0.25}\right) \left(\frac{0.25}{43{,}560}\right) \left(gpa_i\right)$$

which reduces to

$$0.00001147842 \times I \times gpa_i$$

The total estimate in gallons recovered in the 0.5-foot strip is then

$$0.00001147842 \times I \times D$$

where D is the sum, in gallons per acre, of all sample cards.

2. Amount Delivered in 0.5-Foot Strip

The number of feet traveled by the aircraft in one minute =

$$S\left(\frac{5280}{60}\right) = 88 \times S$$

where S is the speed of the aircraft in miles per hour.

Then the number of minutes required to travel 0.5 foot =

$$\frac{0.5}{88 \times S} = \frac{0.00568182}{S}$$

And the number of gallons delivered in 0.5 foot =

$$\frac{0.00568182 \times F}{S}$$

where F is the flow rate of spray in gallons per minute.

3. Per Cent Recovery

Per cent recovery is then

$$100 \left[\frac{0.00001147842 \times I \times D}{(0.00568182 \times F)/S}\right]$$

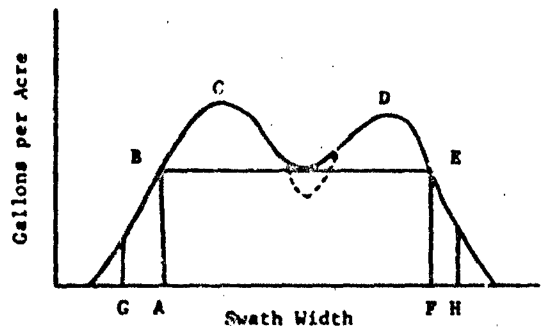
$$= 100 \left[\frac{0.00202 \times S \times I \times D}{F}\right]$$

$$= \frac{0.202 \times S \times I \times D}{F}$$

Considerable variation occurs in the individual per cent recove obtained. Factors contributing to this variation are a summation of er in determining the gallonage per acre, the efficiency of the spray coll tions on the metal plates, the spacing of the sampling stations (in thi case representing only a 2½ per cent sample), and air turbulence that causes the spray to fold back on itself so that the sampling plates may receive a double exposure. The latter instance plus underestimating F overestimating S, could cause "recoveries" greater than 100 per cent.

C. EFFICIENCY OF DEPOSIT

In an effort to arrive at a means to equate spray releases and resulting deposit curves to some efficiency factor, the following was adopted. Refer to a bimodal deposit curve:



where:

AF represents the effective single swath width

GH represents effective swath where multiple swaths are flown

BE represents the desired deposit level

C and D represent deposit peaks.

The amount of deposit above the line BE should be minimized to efficiency of spray deposit. Areas under the curve to the left of and to the right of EF can be considered inefficient utilization of only if single swaths are contemplated operationally. Where multipl spray swaths are laid down, a wider spacing of flight lines (GH) ca use of the deposit in these areas.

1. Calculations of Deposit

Calculations of the efficiency of deposit were based on a si swath, considering both peaks and tails of the curves as areas of w Also included as waste were losses encountered between spray release

deposit. Eighty per cent of the desired deposit level w acceptable, particularly in the central low portion of t practice, there is usually a tendency for flight heading off of inwind and as a result the central low portion of curve is filled somewhat with the finer droplets from th the spray swath.

Per cent efficiency was calculated as

$$\left[\frac{\text{Effective amount recovered in 0.5-ft strip}}{\text{Amount delivered in 0.5-ft strip}}\right]$$

$$\text{Per cent efficiency} = \frac{0.202 \times S \times I \times E}{P}$$

where

$$E = \sum_{i=1}^{n} e_i$$

The quantity e_i is defined for the i-th station as an "ef and takes the following values according to the value of acre, gpa, per station, where P is the desired deposit le

when $gpa_i > P$,	$e_i = P$
when $0.80P \leq gpa_i \leq P$,	$e_i = gpa_i$
when $gpa_i < 0.80P$	$e_i = 0$

Data on multiple inwind or crosswind swaths were However, under these conditions the deposit represented i of the curves would be additive if appropriate spacing of was achieved, so that these deposits would not be conside Therefore, the efficiency of deposit would be expected to statistical analysis of the factors affecting efficiency included as Appendix D.

2. Theories of Deposit

According to Potts,[8] dissemination of an aerosol composed wholly of 300-micron particles would result in 4 square inch. He does not define the characteristics of t Better coverage could be achieved with 200-micron particl per square inch) or 100-micron particles (1164 droplets p Table I shows coverages, times, and drift distances calcul

theoretical principles of spray deposition. These are, of course, ideals only. It is impossible in practice to disseminate an aerosol composed exclusively of particles of one diameter. Because of meteorological conditions and equipment limitations, it is equally impossible to achieve precisely uniform coverage.

TABLE I. SOME PRINCIPLES OF SPRAY DEPOSITION

Size and number of droplets deposited per square inch by distributing one gallon of liquid uniformly over a surface of one acre

Actual Diameter, microns	Number of Droplets Per Square Inch
50	9,224
100	1,164
200	142
300	43
400	18
500	9

The time required for droplets of various sizes with a specific gravity of 1.0 to fall 50 feet in still air at 70°F

Diameter, microns	Time to Fall 50 Feet
200	13 seconds
100	51 seconds
50	3.4 minutes

The distances that a droplet 100 microns in diameter with a specific gravity of 1.0 will drift while falling 50 feet in air moving parallel to the ground

Wind Velocity, miles per hour	Drift Distance, feet
1	87
2	175
3	265
4	348
5	435
10	765

For practical purposes a 50-micron droplet may drift about four times and a 200-micron droplet about one-fourth of these distances.

IV. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

The spray calibration data obtained in these and in the 1962 trials at Eglin Air Force Base are unique in that the spray releases were made inwind and crosswind at greater altitudes, flow rates, airspeeds, and droplet sizes not tested previously for dispersing herbicides for military purposes.

These data are, to the writers' knowledge, the most extensive of their kind ever accumulated. For the fullest contribution possible to the advancement of knowledge in this relatively unique field, these data should be extensively examined by an operations research group capable of discovering principles applicable to the art and statistical tools useful in their evaluation.

Currently it is estimated that of the liquid spray released 50 per cent or less is likely to be utilized efficiently.

1. C-123/MC-1

From the performance data of the C-123/MC-1 (aircraft 56-4386) research configuration, it is concluded that:

(a) A reliable flow meter is essential for testing a system for operations and desirable for inclusion in operational situations.

(b) A deposit of three gallons per acre can be obtained with any of three liquids sprayed on a single inwind pass at 150 feet and 150 miles per hour; however, peaks of deposit occur on inwind flights that exceed 10 gallons per acre in some cases.

(c) At high flow rates the spray from the tail boom tends to fill in the valley or trough of a normally bimodal deposit curve and generally causes a central deposit peak.

(d) Deposit peaking in these tests could have been caused in part by relatively large particle sizes in sprays (about 350 micron MMD's and larger), particularly on inwind flights where high flow rates were tested.

(c) Two 20-horsepower gasoline engine centrifugal pump combinations are not required for one 1000-gallon tank spraying Purple at a rate of 1½ gallons per acre. However, one of these engine-pump combinations would be a desirable replacement for the original 10-horsepower unit currently in use on Modification 1, because the latter unit must be operated at full throttle to provide sufficient flow of Purple for a 1½-gallon deposit per acre.

(f) Two 20-horsepower gasoline engine pump combinations are required for each 1000-gallon tank to spray Purple code material, a 2:1 mix of fuel oil and Purple, or fuel oil at a rate sufficient for a deposit of three gallons per acre.

(g) Booms of three-inch diameter are not required. Liquid surging in them caused the check valves to malfunction. This condition was corrected by installing booms 1½ inches in diameter.

(h) Two gallons per acre of Purple is the maximum practical deposit to be obtained on inwind flights where 1½-inch-diameter wing booms only are functioned and the flow rate is of the order of 430 gallons per minute using both pumps. Under these conditions the recovery of spray released could be expected to be 80 to 100 per cent in an effective swath of about 240 feet. Where all three booms may be functioned a deposit of three gallons per acre could be expected for the same swath, and at about the same per cent recovery.

(i) Where only one pump is used for spraying Purple at a rate of 280 gallons per minute through 98 one-fourth-inch check valves using 1½-inch-diameter wing booms in an attempt to obtain a deposit of 1½ gallons per acre, an MMD of about 400 microns, 93 per cent recovery of spray, and an inwind swath of about 300 feet can be expected. Functioning all booms and using 110 check valves for spraying can be expected to provide about the same flow rate, swath, and per cent recovery.

2. H-34/HIDAL

In regard to the H-34/HIDAL modified system, it is concluded that:

(a) The functioning reliability of the system is improved as modified.

(b) The modified unit can provide an MMD of 365 microns in swaths of Purple spray of 190, 160, and 150 feet at deposits of 0.5, 1.0, and 1.5 gallons per acre, respectively, when flown inwind at 55 knots at an altitude of 100 feet using 60 nozzle tips No. 8015.

(c) The unit can be flown at 75 knots and at 75 feet altitude [otherwise as in (b) above] to obtain an MMD of about 300 microns in Purple spray in swaths of 180, 150, and 120 feet at deposits of 0.5, 1.0, and 1.5 gallons per acre, respectively.

(d) Functioning the system without nozzle tips (using the check valves only) tends to increase particle MMD and slightly diminish swath width.

3. General Conclusions

For truly inwind spray flights or for spray flights conducted under wholly quiescent conditions, spray deposit curves generally will have a maximum of peaking. As MMD's of the spray increase, the peaking is intensified.

Ideal conditions for spray release are more likely to be the exception than the rule. Factors contributing to a high degree of spray aimability do not generally increase efficiency of spray deposit.

Where spray aimability is an overriding factor this can best be satisfied by inwind spray releases.

Where spray coverage of large areas is sought, crosswind releases are indicated.

B. RECOMMENDATIONS

1. C-123/MC-1

For the C-123/MC-1 system it is recommended that:

(a) Reliable flow meters with capacities of about 500 gallons per minute be installed.

(b) Wing booms 1½ inches in diameter be continued in use.

(c) Necessary valves and piping be installed on all C-123/MC-1 systems to enable its engine and pump to load the 1000-gallon tank.

(d) If the current requirements — a three-gallon-per-acre deposit delivered in a single pass — are continued, then on inwind flights, a swath of 240 feet and a flow rate of about 430 gallons per minute should be used for Purple spray for flights at 130 knots and at a 150-foot altitude of release. Dual engine-pump combinations and a tail boom would be required.

(e) If two separate passes are to be used, spraying 1½ gallons per acre on each pass, then under the conditions of (d) above, a swath of 300 feet and a flow rate of about 260 gallons per minute should be used. For military or operational reasons these two passes need not be made on the same mission. If a second 1½-gallon dose is necessary, a single separate pass at a later date (as much as four to six weeks later) will be at least as efficient and more desirable operationally.

(f) A single 20-horsepower gasoline engine and pump combination should replace the original 10-horsepower units in Modification 1 only as replacements are needed.

(g) The C-123/MC-1 Modification 1 be continued in use.

2. H-34/HIDAL

For the H-34/HIDAL system it is recommended that:

(a) The modification as tested be incorporated into all HIDAL systems used for spraying herbicidal materials.

(b) This HIDAL system as modified be known as HIDAL-70 (for 70 gallons per minute flow rate).

(c) That flight conditions be selected from those found in Conclusions, Section IV, A, 2.

(d) That at least 60 nozzle stations be utilized with nozzle tips no smaller than No. 8010 to prevent undue back pressure on the electrically driven positive-displacement pump.

(e) That requests for specifications and or drawings of the HIDAL-70 be addressed to O&R, Naval Air Station, Jacksonville, Florida.

(f) A single 20-horsepower gasoline engine and pump combination replace the original 10-horsepower units in Modification 1 only as ments are needed.

(g) The C-123/MC-1 Modification 1 be continued in use.

H-34/HIDAL

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(e) That requests for specifications and or drawings of the) be addressed to O&R, Naval Air Station, Jacksonville, Florida.

APPENDIX A

SELECTION AND RANKING OF FLIGHTS

C-123/MC-1

Flights Selected for Further Evaluation of Data[a]/

Date 1963	Flight	Liquid[b]/	Booms[c]/	Boom Size	Deposit Attempted, gpa
18 Jul	5	1	WT	1.5	1.5
20 Jul	4	1	WT	1.5	1.5
19 Jul	8	1	WT	1.5	1.5
19 Jul	3	1	WT	1.5	3
19 Jul	6	1	WT	1.5	3
18 Jul	1	1	WT	1.5	3
12 May	1	1	WT	3	1.5
14 May	2	1		3	3
19 May	3	1	WT	3	3
19 May	5	1	[illegible]	3	3
21 May	1	1	WT	3	3
22 May	3	1	WT	3	3
17 May	1	1	WT	3	3
19 May	1	1	WT	3	3
19 May	2	1	WT	3	3
20 May	1	1	WT	3	3
21 May	2	1	WT	3	3
22 May	1	1	WT	3	3
22 May	2	1	WT	3	3
14 May	1	1	WT	3	3
17 May	2	1	WT	3	3
17 May	3	1	WT	3	3
21 May	3	1	WT	3	3
21 May	4	1	WT	3	3
21 May	5	1	WT	3	3
18 Jul	6	1	W	1.5	1.5
20 Jul	6	1	W	1.5	1.5
20 Jul	5	1	W	1.5	1.5
18 Jul	3	1	W	1.5	3

Date 1963	Flight	Liquid	Booms	Boom Size	Deposit Attempted, gpa
19 Jul	7	1	W	1.5	3
20 Jul	7	1	W	1.5	3
23 May	1	1	W	3	1.5
24 May	1	1	W	3	1.5
24 May	3	1	W	3	1.5
24 May	4	1	W	3	1.5
23 May	2	1	W	3	1.5
22 May	4	1	W	3	3
15 May	1	1	W	3	3
22 May	5	1	W	3	3
17 Jul	5	2	WT	1.5	1.5
6 Jul	3	2	WT	1.5	3
6 Jul	4	2	WT	1.5	3
9 Jul	1	2	WT	1.5	3
17 Jul	1	2	WT	1.5	3
17 Jul	4	2	WT	1.5	3
9 Jul	2	2	W	1.5	1.5
17 Jul	3	2	W	1.5	3
4 Jul	2	2	W	1.5	3
6 Jul	2	2	W	1.5	3
4 Jul	1	2	W	1.5	3
1 Jul	1	3	WT	1.5	3
13 Jul	6	3	WT	3	3
6 Jul	1	3	WT	3	3
13 Jul	2	3	WT	3	3
25 Jul	2	3	W	1.5	3
13 Jul	5	3	W	3	3

a. Altitude requested 150 feet.
Airspeed requested 130 knots.

b. 1 = Purple Code material.
2 = 1 part Purple, 2 parts fuel oil.
3 = Fuel oil.

c. WT = All booms.
W = Wing booms.
T = Tail booms.

H-34/HIDAL

Flights Selected for Consideration of Data

Date 1963	Flight	Liquid[a]	Altitude,[b] feet	Airspeed,[b] knots	Nozzle[c] Type
16 Jul	8	1	50	55	8015
16 Jul	7	1	50	55	8015
13 Jul	5	1	50	55	C.V.
13 Jul	6	1	50	55	C.V
13 Jul	3	1	50	75	C.V.
13 Jul	4	1	50	75	C.V.
12 Jul	5	1	75	55	8015
16 Jul	15	1	75	55	8015
12 Jul	6	1	75	55	8015
16 Jul	16	1	75	55	8015
12 Jul	10	1	75	55	C.V.
13 Jul	13	1	75	55	C.V.
13 Jul	14	1	75	55	C.V.
16 Jul	13	1	75	75	8015
16 Jul	14	1	75	75	8015
12 Jul	7	1	75	75	8015
12 Jul	8	1	75	75	8015
12 Jul	11	1	75	75	C.V.
13 Jul	10	1	75	75	C.V.
13 Jul	11	1	75	75	C.V.
13 Jul	16	1	75	75	C.V.
13 Jul	9	1	75	75	C.V.
13 Jul	12	1	75	75	C.V.
13 Jul	15	1	75	75	C.V.
16 Jul	6	1	100	55	8015
16 Jul	11	1	100	75	8015
16 Jul	12	1	100	75	8015
[illegible] Jul	17	1	100	75	C.V.

Date 1963	Flight	Liquid[a]	Altitude,[b] feet	Airspeed,[b] knots	Nozzle[c] Type
13 Jul	18	1	100	75	C.V.
7 Jul	6	2	50	55	8010
7 Jul	5	2	50	55	8010
7 Jul	15	2	50	55	8015
8 Jul	5	2	50	75	8C15
8 Jul	6	2	50	75	8015
2 Jul	12	2	50	75	C.V.
8 Jul	14	2	50	75	C.V.
2 Jul	11	2	50	75	C.V.
7 Jul	3	2	75	55	8010
2 Jul	5	2	75	55	8010
5 Jul	3	2	75	55	8015
5 Jul	4	2	75	55	8015
8 Jul	9	2	75	55	8015
8 Jul	10	2	75	55	8015
8 Jul	11	2	75	55	C.V.
8 Jul	12	2	75	55	C.V.
7 Jul	7	2	75	75	8015
8 Jul	4	2	75	75	8015
2 Jul	7	2	75	75	C.V.
2 Jul	1	2	100	55	8010
5 Jul	1	2	100	55	8015
5 Jul	5	2	100	75	8015
5 Jul	6	2	100	75	8015

a. 1 = Purple.
   2 = 1 part Purple, 2 parts fuel oil.
   3 = Fuel oil.
b. Altitudes requested.
   Airspeed requested.
c. C.V. = 1/8-inch check valve with no nozzle tip.
   8010 = 1/8-inch check valve with Spraying Systems flat nozzle tip (rated 1.0 GPM).
   8015 = 1/8-inch check valve with Spraying Systems flat nozzle tip (rated 1.5 GPM).

APPENDIX B

SWATH WIDTHS

C-123/MC-1[a]

Date 1963	Flight	Chemical[b]	Type Attempted[c] Heading	Deposit	Boom[d]	Swath Widths (in ft.) at Indicated Deposit Rates (in gpa) 0.2	0.5	1.0	1.5	2.0	3.0
10 May	1	Shakedown									
	2	Shakedown									
	3	Shakedown									
	4	1	-	3	WT	600	560	290	260	240	220
11 May	1	1	-	3	WT	580	440	400-10	350-100	190-60	170-100
	2	1	X	3	WT	790	540-40	400-10	330	270-60	40
	3	1	X	3	WT	790	460	330	270-100	190-100	0
12 May	1	1	-	1.5	WT	300	280-10	270-60	250-70	240-120	210-150
	2	1	-	1.5	WT	600	350	340-30	290-20	250-70	210-120
	3	1	-	3	WT	800	440	370	290	280-40	240-70
	4	1	X	3	WT	1000	280	60	50	0	0
13 May	1	1	X	3	WT	530	420	230-10	40	10	0
	2	1	X	3	WT	1240	820-30	610	480	370-40	110-60
	3	1	X	3	WT	1200	830-180	490-20	470-120	0	0
14 May	1	1	-	3	WT	1320	570	460-110	330	320	280-30
	2	1	-	3	WT	380	360	290	170	290	280-80
15 May	1	1	-	3	W	520	510-80	350-30	320-60	290-70	270-100
	2	1	-	3	W	1020	890-330	380-10	260	230-60	210-100
17 May	1	1	-	3	WT	420	400	360	350-50	250-10	250-80
	2	1	-	3	WT	640	430	390	280	270	250-40
	3	1	-	3	WT	480	400	340	280	260-40	220-60

	[illegible]	1	X	3	WT	1040	790	580-40	380	310	130
18 May	1	1	X	3	WT	1020	650	600	540	500-140	240-120
	2	1	X	3	WT	940-100	620	420-40	280-100	0	0
19 May	1	1	-	3	WT	300	290	280	270	260	230-50
	2	1	-	3	WT	310	290	270	260	250-10	240-50
	3	1	-	3	WT	250	250	240	240-20	240-30	220-60
	4	1	-	3	WT	350	320	280	240-20	230-60	100-20
	5	1	-	3	WT	300	290	270	270-30	270-50	240-80
20 May	1	1	-	3	WT	500	290	260	240	240	220-30
21 May	1	1	-	3	WT	240	240	220	220-40	210-100	200-120
	2	1	-	3	WT	420-40	250	240	230	230	220
	3	1	-	3	WT	560-20	380	310	300	280	240-40
	4	1	-	3	WT	700-20	380	320	300	260	240
	5	1	-	3	WT	370	360	280	260	230	210-40
	6	1	X	3	WT	600-40	400	320	250	230	200-20
22 May	1	1	-	3	WT	340	310	300	290	280	260-20
	2	1	-	3	WT	310	300	280	270	260-30	250-40
	3	1	-	3	WT	380	300	270	250-20	240-40	240-70
	4	1	-	3	W	320	340	290-60	290-80	280-100	270-100
	5	1	-	3	W	450	410	390-20	320-20	310-30	200-30

a. Airspeed requested at 130 knots (150 mph).
Altitudes requested at 150 feet.

b. 1 = Purple code material.
2 = 1 part Purple, 2 parts fuel oil.
3 = Fuel oil.

c. X = Crosswind.
- = Inwind.
Deposits: 1.5, 3.0.

d. Wt = All booms.
W = Wing booms.
T = Tail booms.

Date 1963	Flight	Chemical[b/]	Type Attempted[c/] Heading	Deposit	Boom[d/]	Swath Widths (in ft.) at Indicated Deposit Rates (in gpa) 0.2	0.5	1.0	1.5	2.0	3.0
23 May	1	1	-	1.5	W	320	300-60	270-100	240-100	230-120	200-160
	2	1	-	1.5	W	300	290-40	270-120	200-100	190-100	180-110
	3	1	-	1.5	W	220-80	200-120	0	0	0	0
	4	1	X	1.5	W	880-40	580-40	310	0	0	0
24 May	1	1	-	1.5	W	300-40	290-80	240-110	230-150	270-160	0
	2	1	-	1.5	W	320-20	300-50	280-70	280-80	230-50	180-100
	3	1	-	1.5	W	330	310-20	260-90	250-100	240-120	220-120
	4	1	-	1.5	W	360	330-40	280-120	220-90	220-100	50
	5	1	-	1.5	W	420	380	240	220-60	80	20
	6	1	X	1.5	W	800-40	540	380-50	140-100	0	0
6 Jun	1	3	-	3	WT	540	480	360	320	300	260-20
	2	3	-	3	WT	620	490	460	320	300-20	120-20
	3	3	-	1.5	WT	940	680-20	70	60	40	0
	4	3	-	1.5	WT	720	500	120	100	80-10	0
	5	3	-	3	W	1040	800-80	320-30	280-80	280-140	230-170
	6	3	X	3	WT	930	920-40	440-20	200	120	0
11 Jun	7	3	-	3	WT	600	300	250	220-60	80	20
13 Jun	1	3	-	3	WT	990-20	620	520	420	400-40	50
	2	3	-	3	WT	520	450	370	350	330	70
	3	3	-	1.5	WT	750	560	340	250-110	0	0
	4	3	-	1.5	WT	540	520	80	60	40	0
	5	3	-	3	W	310	300	290	280	270	260

	6	3	X	3	WT	400	340	300	290	290-20	280-50
24 Jun	1	3	-	3	W	430	400-80	380-100	300-140	280-130	30
	2	3	-	3	W	410	320-20	300-100	290-100	280-130	260-160
	3	3	-	3	WT	410	380	340	280-80	230-140	20
25 Jun	1	3	X	3	W	1010	920-20	400-40	150-40	0	0
	2	3	-	3	W	300	420	400-40	330-80	320-130	300-180
	3	3	-	3	WT	400	380	120	100	40	40
	4	3	-	3	WT	580-60	450	410-40	220-20	160-70	0
	5	3	-	1.5	W	400	290-60	0	0	0	0
	6	3	-	1.5	W	680-40	340-100	0	0	0	0
	7	3	-	1.5	WT	570	.10	0	0	0	0
1 Jul	1	2	-	3	WT	410	350	280-50	270-130	40	20
4 Jul	1	2	-	3	W	520	400	320	310-70	300-100	240-140
	2	2	-	3	W	470	440-40	360	340	300-50	260-140
	3	2	-	3	WT	540	480	270	290	180-120	60
	4	2	-	3	WT	600	520	460	420	400-120	80
	5	2	-	1.5	W	620	450-20	260	0	0	0
	6	2	-	1.5	W	600	490-40	380-60	0	0	0
	7	2	-	1.5	WT	580	500-80	260-100	110	20	0
	8	2	-	1.5	WT	580	440-40	190-20	40	20	0
6 Jul	1	2	-	3	W	980	890	570-60	20	0	0
	2	2	-	3	W	360	340	330-40	330-70	320-90	310-120
	3	2	-	3	WT	530	500	410	340	300-50	210-100
	4	2	-	3	WT	560	500	350	300	280-40	220-80

Date 1963	Flight	Chemical[b/]	Type Attempted[c/] Heading	Deposit	Booms[d/]	Swath Widths (in ft.) at Indicated Deposit Rates (in gpa) 0.2	0.5	1.0	1.5	2.0	3.0
	5	2	-	1.5	W	410	360	280	140-20	120-40	0
	6	2	-	1.5	W	590	360	320	240	100	0
	7	2	-	1.5	WT	940-60	500-20	110	20	0	0
9 Jul	1	2	-	3	WT	610	560-50	390	350	300-80	290-120
	2	2	-	1.5	W	480	410	380	350-50	320-130	40
	3	2	-	1.5	WT	500	540	300	280-80	70	0
	4	2	-	3	W	630-40	420	400	340	320-120	220-100
	5	2	X	3	WT	1030	960	900-80	760-160	660-360	0
17 Jul	1	2	-	3	WT	510	460	440	420-20	370-40	350-180
	2	2	-	3	W	900-20	660-20	420	400-20	340-60	100
	3	2	-	3	W	470	400	370	340-40	320-60	310-200
	4	2	-	3	WT	440	390	330	320-60	300-90	220-140
	5	2	-	1.5	WT	350	340	340-40	320-140	320-230	20
	6	2	X	1.5	W	1250-80	900-100	860-520	170-60	10	0
	7	2	X	1.5	WT	1400	1040-260	0	0	0	0
18 Jul	1	1	-	3	WT	370	340	310	300-40	300-100	30
	2	1	-	3	W	780	580	330	310-40	280-200	0
	3	1	-	3	W	300	280	280-20	270-80	270-90	260-100
	4	1	-	3	WT	340	320-60	210-90	70	60	40
	5	1	-	1.5	WT	410	320	300	290-20	290-70	270-180
	6	1	-	1.5	W	320	310	280-80	270-100	260-120	50
	7	1	X	1.5	WT	1100	520-40	400-60	220	80	20
	8	1	X	3	WT	1460	640	450	440	400-20	180

19 Jul	1	1	-	3	W	1000	740	400	350	330	300-40
	2	1	-	3	WT	760	580	380	350	310	200
	3	1	-	3	WT	300	280	240	250	250-10	240-20
	4	1	-	0	T	180-20	100	80	70	50	40
	5	1	-	0	T	140	130	120	80	70	30
	6	1	-	3	WT	460	420	280	270	260	240-40
	7	1	-	3	W	290	280	250	240-20	240-60	230-100
	8	1	-	1.5	WT	290	270	260	220-20	210-120	40
	9	1	-	3	WT	1120	940-140	600-80	370	350-50	180-20
20 Jul	1	1	-	3	WT	880-40	740-100	420	360	350-50	250-20
	2	1	-	3	W	530	400	380	360	330-30	280-80
	3	1	-	1.5	WT	350	330	320	320	290-70	100
	4	1	-	1.5	WT	280	260	250	240-40	240	220-120
	5	1	-	1.5	W	480	420	330	290-40	260-80	220-120
	6	1	-	1.5	W	300	300	300-60	280-120	280-130	280-140
	7	1	-	3	W	580	430	380	300-20	270-20	250-40
	8	1	-	3	WT	700-40	420	383	320	230	200-60
	9	1	X	3	WT	1040-20	840-40	460-60	280	230	180-40

a. Airspeed requested at 130 knots (150 mph).
Altitudes requested at 150 feet.

b. 1 = Purple Code material.
2 = 1 part Purple, 2 parts fuel oil.
3 = Fuel oil.

c. X = Crosswind.
- = Inwind.
Deposits; 1.5, 3.0.

d. WT = All booms.
W = Wing booms.
T = Tail booms.

H-34/HIDAL[a]

Date 1963	Flight	Chemical[b]	Altitude, ft	Airspeed, knots	Nozzle[c] Type	Swath Widths (in ft.) at Indicated Deposit Rates (in gpa) 0.2	0.5	1.0	1.5	2.0	3.0
27 Jun	1 Shakedown										
	2	3	100	55		840	360	70	0	0	0
4 Jul	1	2	100	55	8010	200	170-10	130-50	40	20	0
	2	2	100	55	8010	270	240	120-80	0	0	0
	3	2	100	75	8010	190	180-40	20	0	0	0
	4	2	100	75	8010	200	40	0	0	0	0
	5	2	75	55	8010	220	210	180-80	40	20	0
	6	2	75	55	8010	280	220-40	110-50	0	0	0
	7	2	75	75	C.V.	240	220	160-30	120-40	120-70	10
	8	2	75	75	C.V.	220	180	110-30	40	30	10
	9	2	100	75	C.V.	340	290-30	170	140-80	10	0
	10	2	100	75	C.V.	420	280	160-30	0	0	0
	11	2	50	75	C.V.	250	210	200-80	140-90	20	0
	12	2	50	75	C.V.	240	220-70	190-100	30	10	0
5 Jul	1	2	100	55	8015	310	230	200	180-20	160-70	0
	2	2	100	55	8015	270	210	160-20	30	10	0
	3	2	75	55	8015	300	220	200	190	180-40	30
	4	2	75	55	8015	200	200	190-20	180-70	180-20	10
	5	2	100	75	8015	260	230-20	180-70	170-120	20	0
	6	2	100	75	8015	350	320-10	190	170-40	150-90	20

	[illegible]	[illegible]	75	75	8015	280	130-30	0	0	0	0
	4	[illegible]	75	75	8015	210	50	0	0	0	0
7 Jul.	1	2	100	75	8010	280	220	100-40	0	0	0
	2	2	100	75	8010	230	200-120	0	0	0	0
	3	2	75	55	8010	240	220	200-50	50	30	0
	4	[illegible]	75	55	8010	280	180	110	70-20	0	0
	5	2	50	55	8010	330	300	230	200-10	180-120	30
	6	2	50	55	8010	290	260	220-50	200-70	180-120	0
	7	2	75	75	8015	300	[illegible]	190	180-1[illegible]0	30	0
	8	2	75	75	8015	300	250-20	40	30	20	0
	9	2	75	55	8015	340	290	180-30	100-10	0	0
	10	2	75	55	8015	500	290-10	180-50	10	0	0
	11	2	100	55	8015	260	[illegible]	20	0	0	0
	12	2	[illegible]	55	8015	380	200-10	20	0	0	0
	13	2	100	75	8015	230	180-10	20	0	0	0
	14	2	100	75	8015	120	100-30	0	0	0	0
	15	2	50	55	8015	250	190	170-10	160-40	150-100	0
	16	2	50	55	8015	410	190-20	110-10	0	0	0

a. All flights [illegible]wind.
   30 nozzles used per boom.

b. 1 = Purple code material.
   2 = 1 part Purple 2 parts fuel oil.
   3 = Fuel oil.

c. C.V. = 1/8-inch check valve with no nozzle tip.
   8010 = 1/8-inch check valve with Spraying Systems flat nozzle tip (rated 1.0 GPM).
   8015 = 1/8-inch check valve with Spraying Systems flat nozzle tip (rated 1.5 GPM).

Date 1963	Flight	Chemical[b]	Altitude, ft	Airspeed, knots	Nozzle[c] Type	Swath Widths (in ft.) at Indicated Deposit Rates (in gpa)					
						0.2	0.5	1.0	1.5	2.0	3.0
[illegible] Jul	1	2	75	55	8015	520	490-150	240	180-30	150-60	0
	2	2	75	55	8015	300	250	170	130	120-20	20
	3	2	75	75	8015	350	150	180-20	110-10	100-30	20
	4	2	75	75	8015	330	240	170	90	50-20	0
	5	2	50	75	8015	280	220	180-40	130-60	0	0
	6	2	50	75	8015	270	220	170-70	160-90	30	0
	7	2	75	75	8015	240	220-20	60-10	20	0	0
	8	2	75	75	8015	260	230	140-60	10	10	0
	9	2	75	55	8015	280	200	180-10	170-70	50	0
	10	2	75	55	8015	320	250	200-10	170-40	130-80	0
	11	2	75	55	C.V.	320	230	220	210-40	200-90	30
	12	2	75	55	C.V.	320	200	160	140	130-40	110-80
	13	2	50	75	C.V.	310	180-20	150-80	20	0	0
	14	2	50	75	C.V.	200	190	180-50	10	0	0
12 Jul	1	1	100	75	8015	350	290-10	140-60	20	0	0
	2	1	100	75	8015	280	170	70	30	0	0
	3	1	75	75	8015	360	350-60	220-30	140-10	100-20	30
	4	1	75	75	8015	300	290-10	280-90	180-50	100-50	10
	5	1	75	55	8015	350	330	250	190-30	170-40	140-100
	6	1	75	55	8015	290	280	220	170-10	130-20	120-50
	7	1	75	75	8015	210	180	170	110	100-20	90-60
	8	1	75	75	8015	230	220	140	130	100-20	0

	9	1	75	55	C.V.	250	180	120	110	100	80-30
	10	1	75	55	C.V.	250	170	130-10	110-20	100-20	90-40
	11	1	75	75	C.V.	230	190	170-10	150-10	140-30	120-60
	12	1	75	75	C.V.	[illegible]	230	180	100	90-10	20
	13	1	75	55	C.V.	240	230	220	190-30	90	80-30
	14	1	75	55	C.V.	250	240	210-40	200-60	200-110	40
13 Jul	1	1	75	75	C.V.	300	220-10	160-20	100-10	60-20	0
	2	1	75	75	C.V.	250	230-10	120	100-10	100-30	20
	3	1	50	75	C.V.	220	170-10	160-20	150-30	150-40	110-50
	4	1	50	75	C.V.	260	230	140-10	130-20	120-40	10
	5	1	50	55	C.V.	190	180-10	150-20	130-20	120-40	30
	6	1	50	55	C.V.	220	180	160-30	150-30	140-40	30
	7	1	75	55	C.V.	250	230	180	130	130	100-60
	8	1	75	55	C.V.	260	250-30	150	130	120-20	30
	9	1	75	75	C.V.	140	120-10	100-20	90-30	80-40	0
	10	1	75	75	C.V.	190	130-10	120-20	110-20	100-40	40
	11	1	75	75	C.V.	320	280-20	230-50	180-40	150-60	30
	12	1	75	75	C.V.	290	250-10	130	110	100	90-30
	13	1	75	55	C.V.	260	200	150	120-20	110-30	100-50
	14	1	75	55	C.V.	260	230-50	140-10	130-20	120-40	100-60
	15	1	75	75	C.V.	170	130	120-20	110-40	110-50	100-40
	16	1	75	75	C.V.	180	150	130-10	120-20	110-30	100-50
	17	1	100	75	C.V.	260	130	130-10	120-80	110-80	10
	18	1	100	75	C.V.	200	170-20	160-30	150-90	30	20

Date 1963	Flight	Chemical[b]	Altitude, ft	Airspeed, knots	Nozzle[c] Type	Swath Widths (in ft.) at Indicated Deposit Rates (in gpa)					
						0.2	0.5	1.0	1.5	2.0	3.0
16 Jul	1	1	75	55	8015	220	180-20	140-40	40	0	0
	2	1	75	55	8015	230	200	160-40	130-70	0	0
	3	1	75	75	8015	210	150	130-10	110-70	0	0
	4	1	75	75	8015	380	360-90	160-30	140-70	0	0
	5	1	100	55	8015	280	230-20	160	130-10	110-40	20
	6	1	100	55	8015	290	250-30	160	150-50	30	0
	7	1	50	55	8015	260	210-20	140-50	120-70	20	0
	8	1	50	55	8015	240	210-10	190-70	160-80	160-100	0
	9	1	50	75	8015	330	330	150-40	30	20	10
	10	1	50	75	8015	330	290	190	130-40	30	0
	11	1	100	75	8015	190	190-20	170-70	150-80	30	0
	12	1	100	75	8015	200	190	180-30	170-90	160-100	0
	13	1	75	75	8015	180	160	150	130-40	120-80	0
	14	1	75	75	8015	230	210	180-20	170-60	160-80	30
	15	1	75	55	8015	260	200	170-30	140-50	130-70	0
	16	1	75	55	8015	280	230	220-40	210-30	30	10

a. All flights inwind.
30 nozzles used per boom.

b. 1 = Purple code material.
2 = 1 part Purple, 2 parts fuel oil.
3 = Fuel oil.

c. C.V. = 1/8-inch check valve with no nozzle tip.
8010 = 1/8-inch check valve with Spraying Systems flat nozzle tip (rated 1.0 GPM).
8015 = 1/8-inch check valve with Spraying Systems flat nozzle tip (rated 1.5 GPM).

APPENDIX C

MMD OF SPRAY

Deposit from H-34/HIDAL
Mass Median Diameter (MMD) of Spray

Date 1963	Flight	Liquid[a]	Altitude, ft	Airspeed, knots	Nozzle[b] Type	MMD, microns
27 Jun	1	3	100	55		265
	2	3	100	55		303
2 Jul	1	2	100	55	8010	315
	2	2	100	55	8010	315
	3	2	100	75	8010	237
	4	2	100	75	8010	250
	5	2	75	55	8010	308
	6	2	75	55	8010	295
	7	2	75	75	C.V.	360
	8	2	75	75	C.V.	302
	9	2	100	75	C.V.	383
	10	2	100	75	C.V.	302
	11	2	50	75	C.V.	308
	12	2	50	75	C.V.	270
5 Jul	2	2	100	55	8015	364
	4	2	75	55	8015	308
	6	2	100	75	8015	237
	7	2	75	75	8015	224
7 Jul	1	2	100	75	8010	231
	3	2	75	55	8010	237
	5	2	50	55	8010	273
	8	2	75	75	8015	270
	9	2	75	55	8015	[illegible]
	12	2	100	55	8015	295
	14	2	100	75	8015	184

Date 1963	Flight	Liquid[a]	Altitude, ft	Airspeed, knots	Nozzle[b] Type	MMD, microns
7 Jul	16	2	50	55	8015	289
8 Jul	3	2	75	75	8015	237
	6	2	50	75	8015	218
	10	2	75	55	8015	282
	12	2	75	55	C.V.	418
	13	2	50	75	C.V.	295
12 Jul	1	1	100	75	8015	318
	5	1	75	55	8015	379
	8	1	75	75	8015	312
	11	1	75	75	C.V.	448
	14	1	75	55	C.V.	461
13 Jul	2	1	75	75	C.V.	429
	4	1	50	75	C.V.	474
	6	1	50	55	C.V.	487
	11	1	75	75	C.V.	448
	13	1	75	55	C.V.	435
	17	1	100	75	C.V.	468
16 Jul	1	1	75	55	8015	448
	4	1	75	75	8015	312
	5	1	100	55	8015	364
	8	1	50	55	8015	364
	9	1	50	75	8015	318
	11	1	100	75	8015	331

a. 1 = Purple code material.
2 = 1 part Purple, 2 parts fuel oil.
3 = Fuel oil.

b. C.V. = 1/8-inch check valve with no nozzle tip.
8010 = 1/8-inch check valve with Spraying Systems flat nozzle tip (rated 1.0 GPM).
8015 = 1/8-inch check valve with Spraying Systems flat nozzle tip (rated 1.5 GPM).

C-123/MC-1

Mass Median Diameter (MMD) of Spray[a]

Date 1963	Flight	Liquid[b]	Deposit[c] Attemped, gpm	Nozzle[d] Type	MMD, microns
10 May	1	1	Max	U50120	348.7
11 May	2	1	3	U50120	457.6
11 May	3	1	3	U50120	411.6
12 May	4	1	3	U50120	348.7
13 May	1	1	3	U5070	400.2
13 May	2	1	3	U5070	423.1
13 May	3	1	3	U5070	434.5
17 May	4	1	3	U5070	417.4
18 May	1	1	3	U5070	451.7
18 May	2	1	3	U5070	428.8
21 May	6	1	3	3/8" C.V.	388.8
23 May	4	1	1.5	3/8" C.V.	423.1
24 May	6	1	1.5	3/8" C.V.	411.7
25 Jun	1	3	3	1/4" C.V.	340.0
9 Jul	5	2	3	1/4" C.V.	373.6
17 Jul	6	2	1.5	1/4" C.V.	305.4
17 Jul	7	2	1.5	1/4" C.V.	316.7
18 Jul	7	1	1.5	1/4" C.V.	417.2
19 Jul	9	1	3	1/4" C.V.	423.1
20 Jul	9	1	3	1/4" C.V.	405.9

a. Altitude requested 150 feet.
Airspeed requested 130 knots.
b. 1 = Purple code material.
2 = 1 part Purple, 2 parts fuel oil.
3 = Fuel oil.
c. 3-inch boom 10 May thru 24 May.
1½-inch boom 25 June thru 20 July.
d. 1 8-inch check valve with nozzle U50120.
3/8-inch check valve with nozzle U5070.
3/8-inch check valve with no nozzle tip.
1/4-inch check valve with no nozzle tip.

APPENDIX D

ANALYSIS 6325

FACTORS AFFECTING PER CENT RECOVERY AND EFFICIENCY OF DEPOSIT FOR SELECTED ARPA SPRAY CALIBRATION TRIALS

Prepared for

Crops Division

4 May 1964

Biomathematics Division
DIRECTOR OF TECHNICAL SERVICES

Analysis 6325
4 May 1964
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FACTORS AFFECTING PER CENT RECOVERY AND PER CENT EFFICIENCY FOR SELECTED ARPA SPRAY CALIBRATION TRIALS

PROBLEM: To determine the effect of various factors on per cent recovery and per cent efficiency for selected flights of the HIDAL and C-123 systems.

ANALYZED BY: Marian W. Jones and Dr. Gordon L. Jessup, Jr.

REQUESTED BY: Dr. James W. Brown, Crops Division

REFERENCE: Analysis 6275, Biomathematics Division, 27 February 1964.

SUMMARY

All flights in the 1963 ARPA Spray Calibration Trials were rated subjectively by the investigators using the scale 1 through 4, where 1 represents the best patterns and 4 the worst patterns. The per cent recovery* and per cent efficiency* of sprays were computed for all HIDAL and C-123 flights that resulted in patterns rated as 1, 2 or 3. These data were examined to determine the effects of the various factors involved in the calibration.

"Liquid" was the only factor that was shown to affect per cent recovery for the HIDAL system; "altitude," "speed," "nozzle," and "pattern rating" were also considered. The geometric mean per cent recovery with Purple was estimated as 82 per cent, for "Mix" the estimate was 62 per cent.

For a selected deposit of 1.5 gallons per acre (gpa), only "Liquid" was shown to affect per cent efficiency; significantly 39 per cent was estimated for Purple and 30 per cent for Mix.

Per cent recovery for the C-123 system was significantly affected by "Liquid" and "Intended Deposit," but not by "Booms," "Boom Size," or "Pattern Rating." Geometric mean per cent recoveries were estimated as:

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* Per cent recovery is defined as the ratio of the total amount deposited to the amount of spray released, expressed as a per cent. Per cent efficiency is the ratio of the amount deposited at a given level to the amount disseminated, expressed as a per cent.

Liquid	Intended Deposit 1.5 gpa	3.0 gpa
Purple, %	78	94
Mix or Fuel Oil, %	60	72

None of the factors considered significantly affected per cent efficiency for the C-123 system. The geometric mean per cent efficiency was estimated as 35 per cent.

I. INTRODUCTION

All deposit patterns obtained in the 1963 AMPA Spray Calibration Trials were rated subjectively by the investigators using the scale 1 through 4, where 1 represents the best patterns and 4 the worst patterns. For the systems HIDAL and C-123, per cent recovery and per cent efficiency were computed for each pattern rated 1, 2 or 3.

Per cent recovery is defined as the ratio of the total amount deposited to the amount of spray released, expressed as a per cent. Per cent efficiency is the ratio of the amount deposited at a given level to the amount dissemi-nated, expressed as a per cent. These measurements were computed by the following formulae:

$$\% \text{ recovery} = \frac{0.202 \times S \times D \times I}{F} \quad (1)$$

where: 0.00202 is a constant representing the portion of an acre covered in 1 minute at 1 mph with a swath width of 1 foot. Multiplied by 100 to convert to percentage, the constant becomes 0.202.

S = speed of aircraft in miles per hour

D = total deposit collected on sample line in gallons per acre

I = interval of sample stations in feet

F = flow rate of spray in gallons per minute

$$\% \text{ efficiency} = \frac{0.202 \times S \times I \times E}{F} \quad (2)$$

where: $E = \sum_{i=1}^{n} e_i$

The quantity e_i is defined for the i-th sample station as an "effective deposit," and takes the following values according to the value of gpa per station, where P is the desired deposit level:

when $gpa_i > P$,	$e_i = P$
when $0.80P \leq gpa_i \leq P$,	$e_i = gpa_i$
when $gpa_i < 0.80P$,	$e_i = 0$

Estimates of these percentages are shown in the Annex as Table 5 for HIDAL, and Table 6 for C-123. It was desired to know whether the various factors involved in the calibration, such as altitude, speed, nozzle, etc., affected per cent recovery and per cent efficiency.

II. ANALYSIS

A. METHOD AND MODEL

Considerable variation occurred in per cent recovery and per cent efficiency and, since variances of per cents are usually correlated with $(\text{means})^2$, the logarithmic transformation was used. Variables for analysis were therefore "log % recovery" and "log % efficiency."

A complete least squares analysis was necessary because of the lack of balance among treatment conditions. For instance, in the HIDAL system, data include only 9 flights at an altitude of 100 feet, with 29 flights at 75 feet and 14 flights at 50 feet. In only 5 of these flights were the check valve bodies without nozzle tips* used; the 8015 and 8010 nozzle tips were used in 25 and 22 flights respectively. Thus arithmetic means are comparable neither among the altitudes nor among nozzles.

The mathematical model for the general least squares analysis, assuming no interactions among treatments, was:

$$y_{ij\ldots l} = \mu + a_i + b_j + \cdots + n_k + e_{ij\ldots l}$$

---

* For this expression CV will be used subsequently.

where:

$y_{ij\ldots l}$ = an individual "log per cent recovery" or "log per cent efficiency"

μ = over-all population mean when equal subclass frequencies exist

a_i = effect of the i-th level of treatment a expressed as a deviation from μ

b_j = effect of the j-th level of treatment b expressed as a deviation from μ

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n_k = effect of the k-th level of treatment n expressed as a deviation from μ

$e_{ij\ldots l}$ = random errors assumed normally and independently distributed with mean 0 and variance σ^2.

From this model an over-all mean, corrected for lack of balance among treatment conditions, and a set of coefficients or constants, one for each level of each treatment, are obtained. The appropriate constants are added to the over-all mean to obtain estimates of the mean logarithms for any specified combinations of treatments. Antilogs of these values yield the estimated geometric mean per cent recoveries or per cent efficiencies. The Annex to this analysis contains all means computed in this manner.

B. HIDAL SYSTEM

Factors considered for the HIDAL system were:

(a) Liquid - Purple and Mix
(b) Altitude - 50, 75, and 100 feet
(c) Speed - 55 and 75 knots
(d) Nozzle - 8015, 8010, and CV
(e) Rating - 1, 2 and 3.

1. Per Cent Recovery

The analysis of variance of "log per cent recovery" is shown in Table 1 of the Annex. In order to check the hypothesis of no interactions among treatment conditions, an estimate of the sampling variation was made from those treatment conditions that were repeated. Seventeen degrees of freedom were available for this estimate, giving a mean square of 0.01148 for sampling error. This estimate is equivalent to the error shown in Table 1 of the Annex, which includes interactions if present. Thus it was concluded that the model described in Section II, A was appropriate.

It will be noted from Table 1 of the Annex that only Liquid was shown to have a significant effect on per cent recovery, and Purple gave a higher per cent recovery than "Mix." Coefficients computed from the least squares analysis and least squares geometric means were:

HIDAL
Per Cent Recovery

Factor	Coefficient	Least Squares Geometric Mean % Recovery
Over-all Mean	1.85387	71.43
Liquid:		
Purple	0.06219	82.43
Mix	-0.06219	61.90
Altitude:		
50 feet	-0.01374	69.20
75 feet	0.03791	77.95
100 feet	-0.02418	67.56
Speed:		
55 knots	-0.02262	67.80
75 knots	0.02262	75.25
Nozzle:		
8015	0.00124	71.63
8010	0.01019	73.12
CV	-0.01143	69.57
Rating:		
1	0.02691	75.99
2	-0.00904	69.96
3	-0.01787	68.55

In spite of the fact that no factor other than Liquid significantly affected per cent recovery, it appears from the means above that the combination of the four controllable factors that would apparently give the highest per cent recovery is: Purple, 75 feet altitude, 75 knots speed, and 8010 nozzle. Flights that were made with this combination of factors and resulted in a pattern rated as 1 would likely have about 100 per cent recovery on the basis of the current method of computing per cent recovery. Approximate 95 per cent confidence limits were 75 to 140 per cent recovery. This treatment combination was not included in the experimental program, therefore estimates given are purely theoretical.

Since the factor of, say, speed was not shown by the analysis to affect per cent recovery significantly, it is worthwhile to determine the number of observations that would be necessary to disclose a difference in speeds of the magnitude of the observed difference. At the 0.05 significance level, with probability of 0.8 of detecting the observed difference of 7.45 per cent between speeds, approximately 60 observations at each speed would be required. Similar numbers of observations would be required to detect observed differences among other factors.

2. Per Cent Efficiency

Only Liquid was shown in Table 2 of the Annex to significantly affect per cent efficiency at an intended deposit level of 1.5 gallons per acre. Computed coefficients and least squares geometric mean per cent efficiencies were:

RIDAL
Per Cent Efficiency - 1.5 gpa

Factor	Coefficient	Least Squares Geometric Mean % Efficiency
Over-all Mean	1.53813	34.53
Liquid:		
Purple	0.05470	39.16
Mix	-0.05470	30.44
Altitude:		
50 feet	-0.02641	32.49
75 feet	0.01690	35.89
100 feet	0.00952	35.29
Speed:		
55 knots	-0.01097	33.66
75 knots	0.01097	35.41
Nozzle:		
8015	0.07494	41.03
8010	-0.06296	29.87
CV	-0.01199	33.59
Rating:		
1	0.04991	38.73
2	-0.03009	32.21
3	-0.01983	32.99

Observed values indicated that, with the exception of nozzle, the same combination of factors that may produce the greatest per cent recovery might also produce the greatest per cent efficiency when intended deposit is 1.5 gallons per acre. That is, Purple, 75 feet altitude, 75 knots speed, and 8015 nozzle gave an estimated per cent efficiency of 55 per cent with 95 per cent confidence limits of 45 to 70 per cent for deposit curves rated as 1.

C. C-123 SYSTEM

Factors considered for the C-123 system were:

(a) Liquid - Purple, Mix, and Fuel Oil
(b) Booms - All, or Wing only
(c) Boom Size - 1.5 inches, 3 inches
(d) Intended deposit - 1.5 and 3 gallons per acre
(e) Rating - 1, 2 or 3.

1. Per Cent Recovery

The analysis of variance of "log per cent recovery" for the C-123 system is shown in Table 3 of the Annex. Liquid and intended deposit were shown to affect per cent recovery significantly. A higher per cent recovery was shown with Purple than with either Mix or Fuel Oil, but no significant difference was shown between the latter two liquids. A higher per cent recovery was obtained when the intended deposit was 3 gallons per acre than for 1.5 gallons per acre. Computed coefficients and least squares geometric mean per cent recoveries were:

C-123
Per Cent Recovery

Factor	Coefficient	Least Squares Geometric Mean % Recovery
Over-all Mean	1.85582	71.75
Liquid:		
Purple	0.07757	85.78
Mix	-0.00697	70.61
Fuel Oil	-0.07060	60.98
Booms:		
All	-0.02315	68.02
Wing Only	0.02315	75.64
Boom Size:		
1.5 inches	-0.02674	67.47
3.0 inches	0.02674	76.31
Intended Deposit:		
1.5 gpa	-0.03908	65.58
3.0 gpa	0.03908	78.51
Rating:		
1	-0.00013	71.73
2	0.01186	73.74
3	-0.01174	69.84

Observed values indicate that the combination of factors that may give rise to the greatest per cent recovery was Purple, wing booms only, 3-inch boom size, and intended deposit of three gallons per acre. The least squares geometric mean was 110 per cent for deposit curves from this combination when the pattern was rated as 2. Approximate 95 per cent confidence limits were 90 to 130 per cent.

2. Per Cent Efficiency

Table 4 of the Annex shows the analysis of variance for "log per cent efficiency." This analysis indicates that none of the factors was shown to affect per cent efficiency significantly. Computed coefficients and least squares geometric mean per cent efficiencies were:

C-123
Per Cent Efficiency

Factor	Coefficient	Least Squares Geometric Mean % Efficiency
Over-all Mean	1.54261	34.88
Liquid:		
Purple	0.03283	37.62
Mix	0.03953	38.21
Fuel Oil	-0.07236	29.53
Booms:		
All	-0.01551	33.66
Wing Only	0.01551	36.15
Boom Size:		
1.5 inches	-0.04358	31.54
3.0 inches	0.04358	38.58
Intended Deposit:		
1.5 gpa	-0.03557	32.14
3.0 gpa	0.03557	37.86
Rating:		
1	-0.01801	33.47
2	0.02305	36.79
3	-0.00504	34.48

Although not included in the experimental program, the combination of factors for which observed values indicate the greatest per cent efficiency may be obtained were Mix, wing booms only, 3-inch boom size, and intended deposit of three gallons per acre, for which the least squares geometric mean per cent efficiency was 50 per cent when the rating was 2. Approximate 95 per cent confidence limits were 35 to 70 per cent.

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TABLE 1

JOB NUMBER 6325

ANALYSIS OF VARIANCE

OF

HIDAL

Log Per Cent Recovery

UNITS

LINE NO.	EFFECT	D.F.	SUM OF SQUARES	MEAN SQUARE	ERROR LINE	F	APPROX. PROB.
1	Liquid	1	.155249	.155249	6	16.0	<.001
2	Altitude	2	.038570	.019285	6	1.99	NS
3	Speed	1	.021612	.021612	6	2.23	NS
4	Nozzle	2	.001927	.000964	6	<1	NS
5	Rating	2	.011498	.005749	6	<1	NS
6	Error	43	.416537	.009687	6		
7	TOTAL	51					
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							

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TABLE 2

Job Number 6325

ANALYSIS OF VARIANCE

OF

MIDAL
Deposit of 1.5 gpa

Log Per Cent Efficiency
UNITS

Line No.	Effect	D.F.	Sum of Squares	Mean Square	Error Line	F	Approx. Prob.
1	Liquid	1	.120107	.120107	6	5.99	<.025
2	Altitude	2	.016760	.008380	6	<1	NS
3	Speed	1	.005080	.005080	6	<1	NS
4	Nozzle	2	.112721	.056360	6	2.8[illegible]	NS
5	Rating	2	.040158	.020079	6	1.0[illegible]	NS
6	Error	43	.861653	.020038			
7	TOTAL	51					
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							

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TABLE 3

JOB NUMBER 6325

ANALYSIS OF VARIANCE

OF

C-123

Log Per Cent Recovery

UNITS

LINE NO.	EFFECT	D.F.	SUM OF SQUARES	MEAN SQUARE	ERROR LINE	F_0	APPROX. PROB.
1	Liquid	2	.127101	.063551	6	7.26	<.005
2	Booms	1	.023684	.023684	6	2.71	NS
3	Boom Size	1	.025422	.025422	6	2.90	NS
4	Intended Deposit	1	.051590	.051590	6	5.89	<.025
5	Rating	2	.004473	.002236	6	<1	NS
6	Error	48	.420239	.008755	6		
7	TOTAL	55					
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							

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TABLE 4

ANALYSIS OF VARIANCE

OF

C-123

Log Per Cent Efficiency

UNITS

JOB NUMBER 6325

LINE NO.	EFFECT	D.F.	SUM OF SQUARES	MEAN SQUARE	ERROR LINE	F	APPROX. PROB.
1	Liquid	2	.056563	.028282	6	1.36	NS
2	Booms	1	.010631	.010631	6	<1	NS
3	Boom Size	1	.067517	.067517	6	3.25	NS
4	Intended Deposit	1	.042748	.042748	6	2.06	NS
5	Rating	2	.014760	.007380	6	<1	NS
6	Error	48	.998075	.020793			
7	TOTAL	55					
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							

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ANNEX TO ANALYSIS 6325

Observed geometric means

and

Least squares geometric means as computed from complete
least squares analysis described in text

for

Per Cent Recovery and Per Cent Efficiency

including

Flights rated as 1, 2 and 3 for the

RIDAL and C-123 Systems

TABLE 1

HIDAL
Per Cent Recovery
Table of Means

Liquid	Altitude, ft	Rating	Speed: 55 knots, Nozzle 8015, 1/	2/	3/	8010, 1/	2/	3/	Check, 1/	2/	3/	75 knots, Nozzle 8015, 1/	2/	3/	8010, 1/	2/	3/	Check, 1/	2/	3/
Purple	50	1	-	-	81*	-	-	83*	-	-	79*	-	-	90*	-	-	92*	1	104	87
		2	1	66	74	-	-	76*	1	70	72	-	-	83*	-	-	84*	-	-	80*
		3	1	56	73	-	-	74*	1	82	71	-	-	81*	-	-	83*	1	96	79
	75	1	2	89	91	-	-	93*	-	-	88*	2	98	101	-	-	103*	-	[illegible]	98*
		2	2	95	84	-	-	86*	1	71	81	-	-	93*	-	-	95*	4	97	90
		3	-	-	82*	-	-	84*	2	73	80	2	91	91	-	-	93*	3	88	85
	100	1	-	-	79*	-	-	81*	-	-	77*	1	77	88	-	-	89*	-	-	85*
		2	-	-	73*	-	-	74*	-	-	71*	1	94	81	-	-	82*	-	-	78*
		3	1	77	71	-	-	73*	-	-	70*	-	-	79*	-	-	81*	2	68	77
Mix	50	1	1	53	61	1	70	62	-	-	59*	-	-	67*	-	-	69*	-	-	65*
		2	-	-	56*	1	94	57	-	-	54*	2	63	62	-	-	63*	2	65	60
		3	-	-	55*	-	-	56*	-	-	53*	-	-	61*	-	-	62*	1	62	59
	75	1	2	71	68	-	-	70*	-	-	56*	-	-	76*	-	-	78*	-	-	74*
		2	2	56	63	1	48	64	-	-	61*	-	-	70*	-	-	71*	1	68	68
		3	-	-	62*	1	51	63	2	72	60	2	77	68	-	-	70*	-	-	67*
	100	1	-	-	59*	-	-	61*	-	-	58*	-	-	66*	-	-	67*	-	-	64*
		2	1	72	55	-	-	56*	-	-	53*	1	61	61	-	-	62*	-	-	59*
		3	-	-	54*	1	49	55	-	-	52*	1	58	59	-	-	61*	-	-	58*

1. Number of observations.
2. Observed geometric means.
3. Computed least squares geometric mean.
* Theoretical values based on extrapolations from observed data.

TABLE 2

HIPAL
Efficiency of Deposit at 1.5 Gallons per Acre
Table of Means

			Speed															
			55 knots									75 knots								
			Nozzle									Nozzle								
			8015			8010			Check			8015			8010			Check		
Liquid	Altitude, ft	Rating	1/	2/	3/	1/	2/	3/	1/	2/	3/	1/	2/	3/	1/	2/	3/	1/	2/	3/
Purple	50	1	-	-	48*	-	-	35*	-	-	30*	-	-	50*	-	-	37*	1	44	41
		2	1	36	40	-	-	29*	1	33	33	-	-	42*	-	-	31*	-	-	34*
		3	1	27	43	-	-	32*	1	32	35	-	-	40*	-	-	33*	1	45	37
	75	1	2	48	53	-	-	39*	-	-	32*	2	58	56	-	-	41*	-	-	46*
		2	2	54	44	-	-	32*	1	27	36	-	-	46*	-	-	36*	4	41	38
		3	-	-	45*	-	-	33*	2	33	37	2	51	47	-	-	35*	3	33	39
	100	1	-	-	52*	-	-	38	-	-	43*	1	46	55	-	-	40*	-	-	45*
		2	-	-	43*	-	-	32	-	-	35*	1	66	45	-	-	33*	-	-	37*
		3	1	52	44	-	-	32	-	-	36*	-	-	47*	-	-	34*	2	36	35
Mix	50	1	1	33	37	1	38	27	-	-	30*	-	-	39*	-	-	28*	-	-	32*
		2	-	-	31*	1	53	23	-	-	25*	2	26	32	-	-	24*	2	19	[illegible]
		3	-	-	32*	-	-	23*	-	-	26*	-	-	33*	-	-	24*	1	38	[illegible]
	75	1	2	41	41	-	-	30*	-	-	34*	-	-	43*	-	-	31*	-	-	35*
		2	2	36	36	1	11	25	-	-	28*	-	-	36*	-	-	26*	1	32	29
		3	-	-	35*	1	18	25	2	38	29	2	46	37	-	-	27*	-	-	30*
	100	1	-	-	41*	-	-	29*	-	-	33*	-	-	43*	-	-	31*	-	-	35*
		2	1	44	36	-	-	24*	-	-	28*	1	33	35	-	-	26*	-	-	24*
		3	-	-	36*	1	24	25	-	-	28*	1	24	36	-	-	26*	-	-	30*

1. Number of observations.
2. Observed geometric mean.
3. Computed least squares geometric mean.
* Theoretical values based on extrapolations from observed data.

TABLE 3

C-123
Per Cent Recovery
Table of Means

Liquid	Booms	Rating	Boom Size											
			1.5 Inches [illegible]						3.0 Inches [illegible]					
			1.5 gpm			3.0 gpm			1.5 gpm			3.0 gpm		
			1/	2/	3/	1/	2/	3/	1/	2/	3/	1/	2/	3/
Purple	All	1	2	89	70	1	103	84	1	37	79	5	96	95
		2	1	63	72	1	86	86	-	-	81*	7	97	97
		3	-	-	60*	1	53	81	-	-	77*	6	100	92
	Wing only	1	1	78	78	2	91	93	3	85	88	1	103	105
		2	1	95	83	-	-	96*	1	93	90	1	97	108
		3	1	105	76	1	83	91	1	72	86	1	110	102
Mix	All	1	-	-	50*	-	-	69*	-	-	65*	-	-	78*
		2	-	-	59*	-	-	71*	-	-	67*	-	-	80*
		3	1	55	56	5	68	67	-	-	63*	-	-	76*
	Wing only	1	-	-	64*	1	68	77	-	-	72*	-	-	87*
		2	-	-	66*	2	73	79	-	-	74*	-	-	89*
		3	1	79	62	1	72	75	-	-	70*	-	-	84*
Fuel Oil	All	1	-	-	50*	-	-	60*	-	-	56*	1	81	67
		2	-	-	51*	-	-	61*	-	-	58*	2	80	69
		3	-	-	48*	1	37	58	-	-	55*	-	-	66*
	Wing only	1	-	-	55*	1	62	66	-	-	62*	1	79	75
		2	-	-	57*	-	-	68*	-	-	57*	-	-	77*
		3	-	-	54*	-	-	64*	-	-	61*	-	-	73*

1. Number of observations.
2. Observed geometric mean.
3. Computed least squares geometric mean.
* Theoretical values based on extrapolations from observed values.

TABLE 4

C-123
Efficiency of Deposit
Table of Means

Liquid	Booms	Rating	Boom Size: 1.5 Inches, Deposit, 1.5 gpa, 1/	2/	3/	1.5 Inches, 3.0 gpa, 1/	2/	3/	3.0 Inches, Deposit, 1.5 gpa, 1/	2/	3/	3.0 Inches, 3.0 gpa, 1/	2/	3/
Purple	All	1	2	44	29	1	42	34	1	19	36	5	39	42
		2	1	31	32	1	46	38	-	-	39*	7	45	46
		3	-	-	30*	1	25	35	-	-	37*	6	49	43
	Wing only	1	1	27	31	2	33	37	3	33	38	1	35	45
		2	1	32	34	-	-	40*	1	43	42	1	42	49
		3	1	56	32	1	48	38	1	35	39	1	52	46
Mix	All	1	-	-	30*	-	-	35*	-	-	36*	-	-	42*
		2	-	-	32*	-	-	38*	-	-	40*	-	-	47*
		3	1	30	30	5	35	36	-	-	37*	-	-	44*
	Wing only	1	-	-	32*	1	30	37	-	-	39*	-	-	46*
		2	-	-	35*	2	41	41	-	-	42*	-	-	50*
		3	1	51	33	1	33	38	-	-	40*	-	-	47*
Fuel Oil	All	1	-	-	23*	-	-	27*	-	-	28*	1	45	33
		2	-	-	25*	-	-	30*	-	-	31*	2	47	36
		3	-	-	24*	1	8	28	-	-	29*	-	-	34*
	Wing only	1	-	-	24*	1	29	29	-	-	30*	1	52	35
		2	-	-	27*	-	-	32*	-	-	33*	-	-	39*
		3	-	-	25*	-	-	30*	-	-	31*	-	-	36*

1. Number of observations.
2. Observed geometric mean.
3. Computed least squares geometric mean.
* Theoretical values based on extrapolations from observed values.

TABLE 5

HIDAL

Per Cent Recovery and Per Cent Efficiency for Selected Flights

Selected Deposit of 1.5 gpa

Date	Flight No.	Rating	Per Cent Recovery	Per Cent Efficiency	Date	Flight No	Rating	Per Cent Recovery	Per Cent Efficiency	Date	Flight No.	Rating	Per Cent Recovery	Per Cent Efficiency
2 July	1	1	[illegible]	[illegible]	8 July	9	2	51.2	32.0	13 July	11	2	120.4	66.3
2 July	5	3	51.2	14.3	8 July	10	2	60.1	34.8	13 July	12	3	129.0	44.5
2 July	7	2	67.6	12.3	8 July	11	3	76.8	45.0	13 July	13	3	74.2	32.3
2 July	11	1	61.5	19.0	8 July	12	3	68.1	32.4	13 July	14	3	72.3	33.4
2 July	12	2	65.4	12.7	8 July	14	2	44.1	28.2	13 July	15	3	109.2	36.4
5 July	1	2	[illegible]	44.2	12 July	5	1	114.0	58.7	13 July	16	2	79.9	34.5
5 July	3	[illegible]	[illegible]	64.5	12 July	6	2	111.4	50.1	13 July	7	3	65.7	35.9
5 July	4	1	56.2	34.7	12 July	7	3	91.9	52.9	13 July	18	3	70.3	36.9
5 July	5	2	60.7	32.6	12 July	8	3	89.3	53.9	16 July	6	3	77.2	52.1
5 July	6	3	57.6	24.5	12 July	10	2	70.5	26.7	16 July	7	3	53.9	27.0
7 July	3	2	[illegible]	10.8	12 July	11	2	111.3	45.5	16 July	8	2	65.8	34.3
7 July	5	2	[illegible]	53.3	13 July	3	1	105.7	44.0	16 July	11	1	77.3	45.1
7 July	6	1	69.9	[illegible]	13 July	4	3	95.6	44.5	16 July	12	2	96.1	61.6
7 July	7	3	[illegible]	48.9	13 July	5	2	70.1	33.4	16 July	13	1	87.9	[illegible]
7 July	15	1	52.8	32.9	13 July	6	3	82.3	32.3	16 July	14	1	109.1	54.8
8 July	4	3	76.8	43.6	13 July	9	3	69.1	22.8	16 July	15	1	69.9	[illegible]
8 July	5	2	[illegible]	26.2	13 July	10	2	80.9	30.3	16 July	16	2	81.3	[illegible]
8 July	6	2	63.1	26.2										

TABLE 6

C-123
Per Cent Recovery and Per Cent Efficiency for Selected Flights

Date	Flight No.	Rating	Per Cent Recovery	Deposit (gpa) Selected	Deposit (gpa) Computed	Per Cent Efficiency
12 Ma[illegible]	[illegible]	1	37.3	1.5	1.5	19.6
1[illegible] May	3	1	122.7	3.0	3.0	68.0
				3.0	1.5	36.8
1[illegible] May	4	1	115.8	3.0	3.0	50.6
				3.0	1.5	30.4
1[illegible] May	1	2	97.[illegible]	3.0	3.0	42.3
				3.0	1.5	30.0
17 May	1	2	101.[illegible]	3.0	3.0	34.5
				3.0	1.5	34.4
1[illegible] May	2	[illegible]	106.[illegible]	3.0	3.0	51.2
				3.0	1.5	35.9
1[illegible] May	3	3	82.0	3.0	3.0	37.9
				3.0	1.5	32.3
1[illegible] May	1	2	87.9	3.0	3.0	50.2
				3.0	1.5	32.1
19 May	2	2	9[illegible].8	3.0	3.0	54.3
				3.0	1.5	32.8
19 May	3	1	118.7	3.0	3.0	44.8
				3.0	1.5	28.4
1[illegible] May	5	1	97.2	3.0	3.0	56.1
				3.0	1.5	37.3
20 May	1	2	[illegible]9.7	3.0	3.0	36.4
				3.0	1.5	24.7
21 May	1	1	53.8	3.0	3.0	17.1
				3.0	1.5	21.1

Date	Flight No.	Rating	Per Cent Recovery	Deposit (gpa) Selected	Deposit (gpa) Computed	Per Cent Efficiency
21 May	2	2	87.2	3.0	3.0	51.8
				3.0	1.5	25.0
21 May	3	3	98.2	3.0	3.0	50.7
				3.0	1.5	32.0
21 May	4	3	106.6	3.0	3.0	50.7
				3.0	1.5	32.0
21 May	5	3	94.4	3.0	3.0	41.8
				3.0	1.5	29.7
22 May	1	2	100.7	3.0	3.0	58.5
				3.0	1.5	32.3
22 May	2	2	99.7	3.0	3.0	37.5
				3.0	1.5	25.0
22 May	3	1	110.7	3.0	3.0	40.3
				3.0	1.5	26.7
22 May	4	1	103.0	3.0	3.0	34.6
				3.0	1.5	21.6
22 May	5	3	109.7	3.0	3.0	52.2
				3.0	1.5	30.7
23 May	1	1	71.1	1.5	1.5	27.2
23 May	2	3	72.3	1.5	1.5	34.4
24 May	1	1	87.1	1.5	1.5	42.9
24 May	2	2	93.3	1.5	1.5	43.2
24 May	3	1	98.8	1.5	1.5	30.2

TABLE 6 (Continued)

C-123

Per Cent Recovery and Per Cent Efficiency for Selected Flights

Date	Flight No.	Rating	Per Cent Recovery	Deposit (gpm) Selected	Deposit (gpm) Computed	Per Cent Efficiency
6 June	1	2	88.2	3.0	3.0	57.3
				3.0	1.5	34.9
13 June	2	2	-	3.0	3.0	38.0
				3.0	1.5	38.0
13 June	5	1	78.3	3.0	3.0	51.8
				3.0	1.5	28.0
13 June	6	1	80.8	3.0	3.0	45.4
				3.0	1.5	31.9
25 June	2	1	61.7	3.0	3.0	28.6
				3.0	1.5	30.5
1 July	1	3	37.2	3.0	3.0	8.2
				3.0	1.5	16.9
6 July	1	3	72.3	3.0	3.0	33.3
				3.0	1.5	30.2
6 July	2	-	76.9	3.0	3.0	41.8
				3.0	1.5	41.5
6 July	2	2	71.6	3.0	3.0	41.1
				3.0	1.5	25.1
6 July	3	3	70.9	3.0	3.0	30.6
				3.0	1.5	35.1
6 July	4	3	76.1	3.0	3.0	37.6
				3.0	1.5	33.3
9 July	1	3	75.9	3.0	3.0	38.3
				3.0	1.5	37.9
9 July	2	3	78.[illegible]	1.5	1.5	50.5
17 July	1	3	66.6	3.0	3.0	36.5
				3.0	1.5	31.7
17 July	3	1	67.7	3.0	3.0	30.1
				3.0	1.5	32.2
17 July	4	3	56.0	3.0	3.0	33.0
				3.0	1.5	28.9
17 July	5	3	56.7	1.5	1.5	30.3
18 July	1	3	52.9	3.0	3.0	24.8
				3.0	1.5	29.5
18 July	3	1	83.7	3.0	3.0	36.2
				3.0	1.5	21.2
18 July	5	1	85.3	1.5	1.5	44.9
18 July	6	1	78.4	1.5	1.5	27.2
19 July	3	1	103.0	3.0	3.0	42.1
				3.0	1.5	23.2
19 July	6	2	86.0	3.0	3.0	44.4
				3.0	1.5	27.5
19 July	7	1	98.5	3.0	3.0	32.1
				3.0	1.5	21.0
19 July	8	2	63.4	1.5	1.5	31.3
20 July	4	1	91.8	1.5	1.5	42.3
20 July	5	3	105.6	1.5	1.5	56.0
20 July	6	2	95.5	1.5	1.5	31.5
20 July	7	3	83.4	3.0	3.0	47.8
				3.0	1.5	36.6

APPENDIX E

PRELIMINARY PLANNING FOR ARPA SPRAY CALIBRATION TRIALS*

Background

The proposed ARPA calibration trials are in a large measure a continuation of trials conducted at Eglin AFB, Florida, in June and July, 1962. These former trials have been recorded in the following reports:

1. Modification and Calibration of Defoliation Equipment (C-123 - First Modification), July 1962

2. Supplement to Modification and Calibration of Defoliation Equipment (C-123 - First Modification), July 1962

3. Spray Test Calibration of the HIDAL (HUS-1 or H-34), July 1962 (along with authority, implementation, and methods used at that time).

The FIDAL is a new piece of hardware, six units of which have been manufactured by AGAVENCO and will be included in the spring 1963 calibration trials.

Because the levels of spray deposit in the proposed trials will be greater then those encountered in the trials conducted in 1962, the acetone-wash method will be used.

Assumptions

An inherent assumption is that emphasis will be placed on determining factors essential to the future useful operation of these systems rather than on finding our "all there is to know" about them. Although some ancillary information is desirable (and some is provided for in this preliminary planning), it is believed that if further excursion in this area is desired, it should be so indicated to the planner at an early date. Otherwise, if it becomes necessary to curtail any testing, it will be done in the ancillary information area. In this connection, it should be noted that a system developed by Transland Aircraft, Torrance, California, "was flown to . . . . for several months of aerial spray distribution pattern tests." In contrast, this preliminary plan concerns three systems and a total of about 75 days.

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* By J.W. Brown, 25 February 1963.

Proposed Objectives

The major objective of the trials at Eglin AFB will be to calibrate the systems for their spray performance, particularly regarding aimability of the spray and achieving useful deposit levels and particle sizes with Purple code material.

Current guidelines are to obtain, under conditions of inversion and temperatures of 65°F or greater:

C-123/MC-1 (Figures 1-4)

particle MMD - about 300 microns

swath width - 300 feet or greater

deposit - 3 gallons per acre

and determine flow rate settings necessary for such deposits under conditions of 150 mph at 150-foot altitude or higher on inwind flights with wind less than five miles per hour.

For AD-6/FIDAL

particle MMD - about 300 microns

swath width - maximum (to be determined, currently appears to be about 150 feet)

deposit - 3 gallons per acre and maximum

and determine fan pitch settings to obtain flow rates necessary for such deposits under conditions of about 150 knots (173 mph) and appropriate altitudes for greatest effective swath widths.

For H-34/HIDAL (Figures 5 and 6)

particle MMD - about 300 microns

swath width - maximum (to be determined, currently appears to be about 125 feet)

deposit - maximum

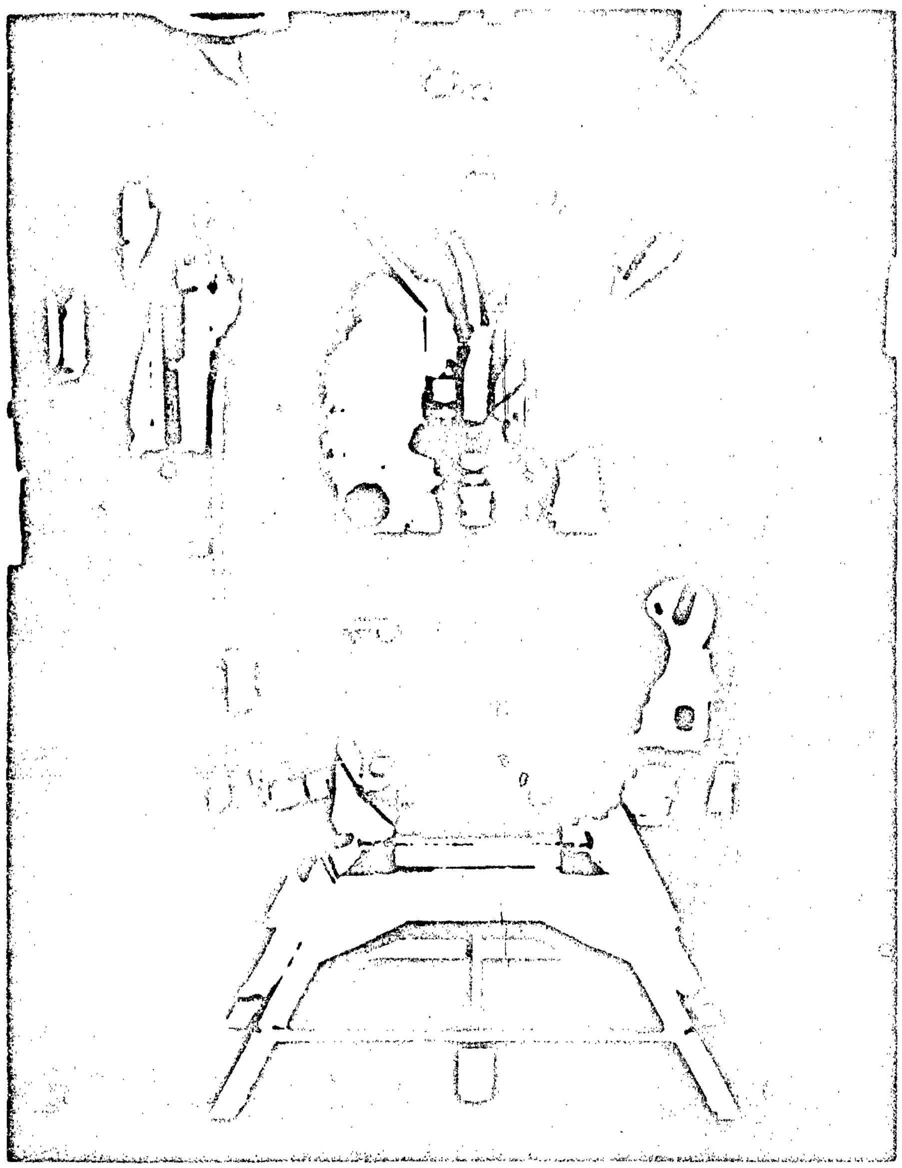

Figure 1. Tank with Engine-Pump Combination (Aft Mount).
(FD Neg C-7046)

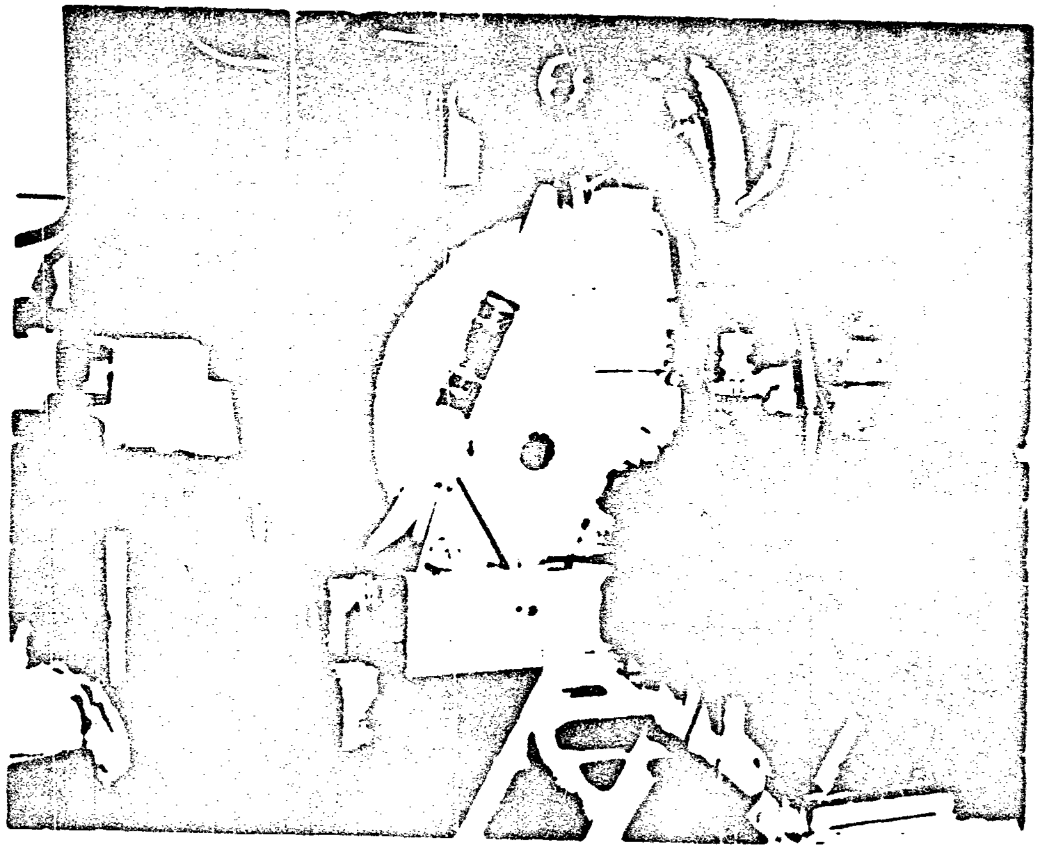

Figure 2. Tank with Engine-Pump Combination (Forward Mount).
(U.S. Air Force Photo)

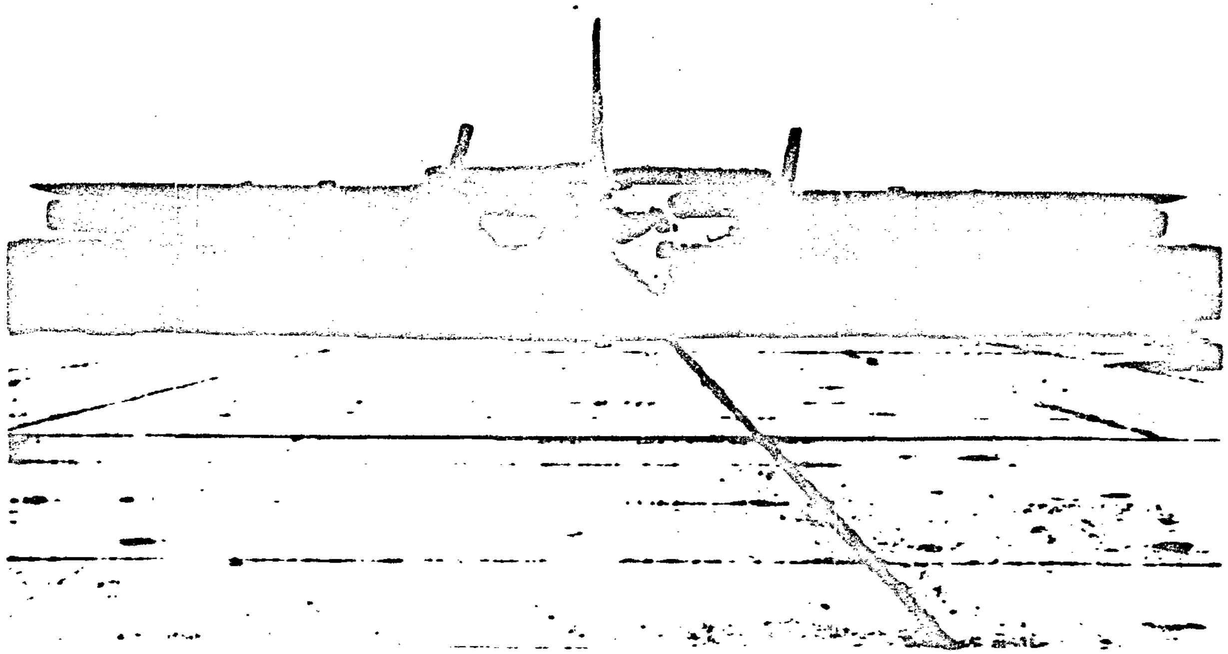

Figure 3. C-123/MC-1 with "Purple Catchers" Mounted for Flow Rate Determinations. (FD Neg C-7039)

Figure 4. C-123/MC-1 Spraying in Flight.
(FD Neg C-7429)

Figure 5. HIDAL Spraying in Flight. (FD Neg C-7036)

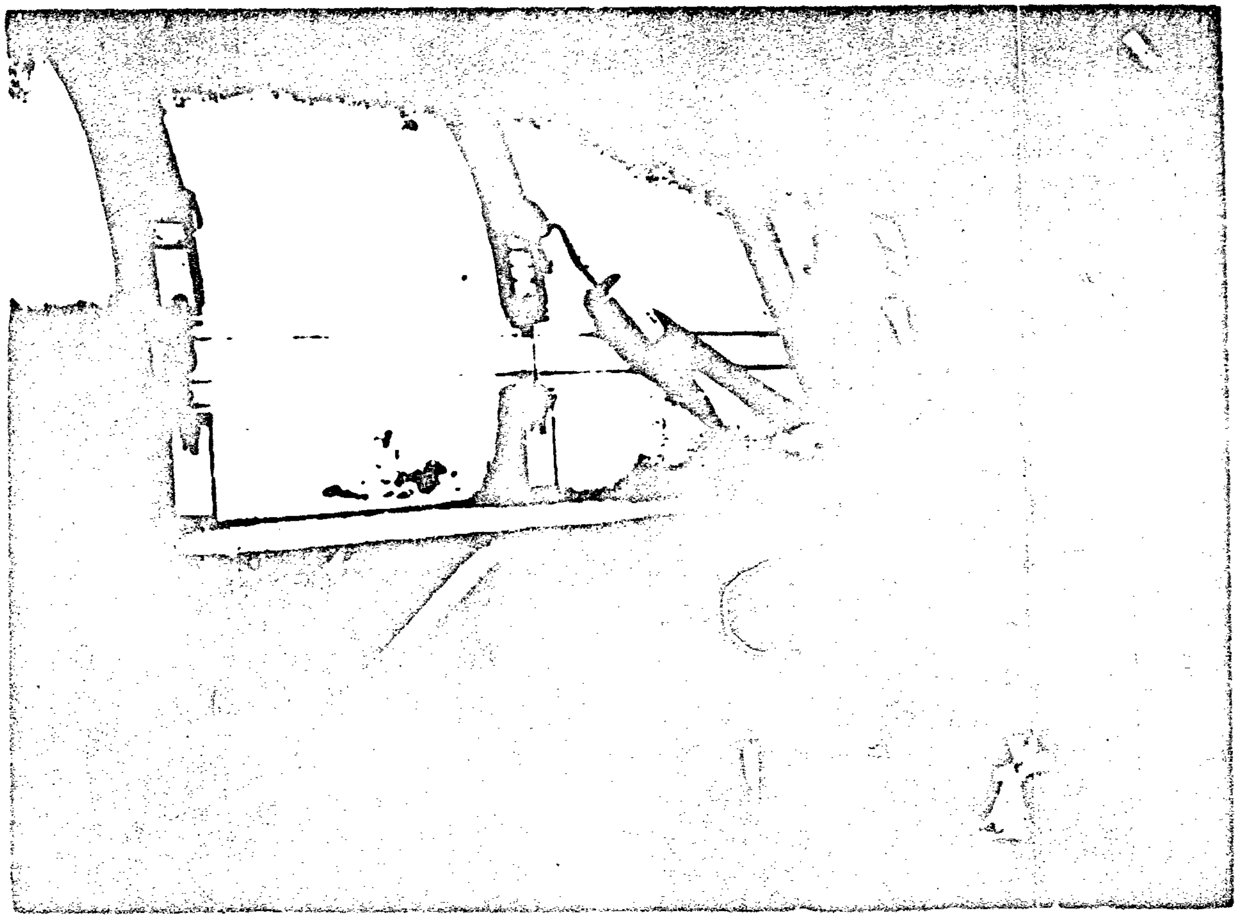

Figure 6. 200-Gallon [illegible] Tank Mounted in an H-34 Helicopter.
([illegible] Neg C-7065)

The NIDAL has a relatively fixed flow rate that can be adapted to ground deposits by number of nozzles, nozzle tips, and/or varying the altitude of release and airspeed. Both of the latter will be varied and a determination made whether an airspeed of about 70 to 75 knots can be safely flown with the rig.

Additional Objectives (all systems):

1. Check ground performance with ground flow rates and aerial sprays of a mixture of 1 part Purple to 2 parts #2 diesel fuel oil, and with the fuel oil.

2. Check ground flow rates with water relative to performance with other solutions. This information could provide a basis for ground field checks of system performance as may be required, e.g., OCONUS.

Notes on Test Objectives

The original OSD/ARPA authorization for calibration involved only the C-123/MC-1 system, but with two modifications of this system. The first one was to provide quickly a system for obtaining 1½ gallons per acre and the second to provide a 3-gallon-per-acre capability. Until the three-gallon modification was ready the first could be and was used to provide 3 gallons per acre by the expedient of flying two passes at 1½ gallons over the same area.

The basic objective of the trials is to ascertain the capabilities of such systems and to recommend configurations for a given capability. Prior to the second trials, most effort was directed toward obtaining the maximum capability of the systems available and to generate ideas for their improvement to increase this maximum.

Where the system output can be varied the objective becomes a set of tables for such variation of system "adjustability." However, it is desirable that this should be done to some extent with the FIDAL.

It is considered desirable to have concurrently available at Eglin at least two different systems and to alternate daily in their use so that a period for aircraft maintenance is possible and more time will be available for the feedback of information collected from one run to the next for a given system so that necessary adjustments can be made as required.

Spray Release versus Deposition

Under inversion conditions, available information indicates that on the average about 65 per cent of spray release is recovered; however, improved data on this point would be welcome and we are prepared to obtain such data using the acetone-wash method.

Concurrently we hope to obtain a comparison of methods, i.e., using dyed cards and the visual estimate of deposit as against the acetone-wash method and thus obtain some standards for the visual method with Purple.

Flow Rates

During the determinations of ground flow rates, it is desirable to compare flow rates of various materials. Because the viscosity of Purple changes rather markedly with temperature, it will be desirable to obtain two or three tests with Purple at different temperatures and, with the same settings, measure the flow rates for fuel oil and water.

Location

The test area selected is APGC, Eglin, AFB, Florida. Range 52 South will be used for the grid. Ground flow rate checks will be conducted and the laboratory will be located at Field 2.

Location and Layout of Chemical Grid

Four lines intersecting centrally are established at Range 52 South. Sample lines are 2000 feet long with stakes at 20-foot intervals.

Support Requirements

U.S.A. Biological Laboratories, Fort Detrick, Maryland

U.S.A. 100th Chemical Group, Fort McClellan, Alabama (vehicles and drivers)

U.S.N. D.V.C.C., NAS, Jacksonville, Florida (HIDAL - modified)

U.S.N. Aircraft 2(H-34 and A-1H aircraft)

U.S.A.F. 4500 Ops. Sq. Langley AFB, Virginia (C-123)

U.S.A.F. PGOPW, Eglin AFB, Florida (support)

U.S.A.F. Tinker AFB, Oklahoma (Meteorological)

U.S.A.F. MAAMA, Olmsted AFB, Pennsylvania (MC-1 - modified)

Contractor, AGAVENCO, Santa Clara, California (FIDAL)

Safety

Laboratory Safety Procedures

1. Laboratory personnel will not smoke within 50 feet of the acetone storage area or in the laboratory when acetone is being used as a solvent.

2. All contaminated acetone will be disposed of in a manner directed by the officer in charge of the laboratory.

Range Safety Procedures

1. Aircraft will not be flown over populated areas when carrying test items.

2. The Project Officer at Eglin AFB will provide the pilot with an approved flight path to and from the range that avoids all populated areas.

3. The aircraft pilot will not dispense any test item except directly over the grid area.

Security

Test results will be UNCLASSIFIED.

Reports

1. Army personnel will be responsible for the preparation of all technical reports.

2. APGC, Eglin will reproduce the reports.

Photography

A photo team from Fort Detrick will be on location to make a documentary film (16-mm color) of all spray systems, operation of laboratory, and grid.

The photography laboratory at Eglin AFB will process certain film

exposed during tests, to include:

1. Rapid processing of film upon request of Project Officer.

2. Four hundred 2- by 2-inch slides from film selected by test team.

3. Glossy black and white prints suitable for half-tone reproduction from negatives furnished by Project Officer.

4. Rapid processing of 16-mm Kodak ER film with one-day service on approximately three 100-foot rolls per day.

Transportation

1. Eight ¼-ton 4 x 4 trucks will be required. These will be furnished by 100th Chemical Group, Fort McClellan, Alabama.

2. One 1½-ton van-type truck with rear door suitable for locking will be furnished by Fort Detrick.

3. Two rental cars are required.

4. One 3/4-ton truck for meteorological group will be furnished by Eglin AFB.

5. Normal maintenance support of the ten military vehicles will be provided by APGC, Eglin AFB.

Communications

1. Two telephones at Field 2 will be located in the hangar presently assigned as the office and laboratory. The telephone will have access to local and long-distance services.

2. Mobile communications for ground to aircraft will be provided by Eglin AFB.

3. Ground-to-ground communication requirement will be eight PRC-10 radios, four from Fort McClellan and four from Fort Detrick.

Notes on System Flights

It is believed that data to be obtained on the conditions of flight listed should be ample to provide a basis for operational dissemination.

As the information is obtained it may indicate stressing the need for more information on a given variable and, vice versa, may allow an early choice of selecting and using a "standard" condition for a given variable or variables.

Latitude of on-the-spot choice should be allowed as the testing proceeds.

<u>Agent Requirements</u>

Estimates are summarized below.

Estimates of Gallons of Purple and #2 Diesel Fuel Oil Required

System	Purple, gallons	Fuel Oil, gallons	Average Release Time per Pass, seconds
C-123/MC-1	7500	9270	20
FIDAL	4800	3080	12
HIDAL	900	1125	20
Total	13200	13475	
On Hand	6500	---	
Additional Required	6700	13475	
Est. Cost/Gal	$5.00	$0.10	
Est. Cost	$33,500	$1,350	
Total Cost			$34,850

In the past with expedited procurement (New York Procurement Office) 5000 gallons of Purple have been obtained on site within two weeks. Fuel oil was obtained locally at Eglin AFB as needed.

Personnel Requirements

Personnel requirements are tabulated in Tables I and II.

Regardless of system, Army personnel indicated in Table I and the Air Force meteorological personnel will be required for the duration of the trials. Other personnel associated with each system will be required on location as long as that system is required.

TABLE I. PERSONNEL REQUIREMENTS (ARMY)

	Number of personnel	Fort Detrick Crops Div.	Fort Detrick Other	Ft. McClellan
Field Crew				
Coordinator	1	1		
Asst. Coordinator	1	1		
Radio Operator	1		1	
Grid Crew	7	2		5
Total	10	4	1	5
Lab. Crew				
Lab. Supervisor	1	1		
Spectrophotometer Operator	2	2		
Lab. Technician	2		2	
Plate Washing	3		3	
Filtering	2		2	
Data Processing	3	3		
Total	13	6	7	
Ground Flow Check				
Equipment Engineer	2		1	
Chemical Dye-Mix	2		2	
Total	4		3	
Photographer	1		1	
Instrument Specialist	1		1	

TABLE II. PERSONNEL REQUIREMENTS SUMMARY

Source of Personnel								
U.S.N.	U.S.A.F.	Contractor	Fort Detrick	Fort McClellan	Civ.	Mil.	Position Description	Number Required
			X		X		Test Director	1
			X		X		Asst. Test Director	1
			X		X		Munition Engineer	1
	X					X	Meteorologist	1
			X		X		Photographer	1
			X		X		Field Foreman	1
			X		X	X	Field Crew	9[1]
				X		X	Drivers	10[1]
			X			X	Lab. Foreman	1
			X			X	Lab. Technicians	12
	X					X	Meteorological Observer	8
		X			X		Electrical Engineer	1
		X			X		Mechanical Engineer	1
			X		X		Instrument Specialist	1
			X			X	Ground Flow Check	
X						X	Air Crew[2]	
	X					X	Air Crew[2]	

1. Five drivers to assist as part of field crew.
2. Number to be determined by appropriate service to provide air support.

Crops Division plans to supply a total of about 11 technical and non technical personnel; about half of these people have been designated. The remainder are anticipated to be available either by reassignment within the Division, transfer to the Division, or by recruitment.

The following Fort Detrick personnel are requested by name for their various specialties:

Photography - Mr. Paul Riley and/or Mr. Al Cissna

Equipment Engineer - Mr. Paul Wampner (to be in charge of ground flow rate checks and system configuration)

Instrument Specialist - Mr. Kenneth Krantz

Laboratory Supervisor - Mr. George Trout

Arrangements are in process or have been completed for appropriate Air Force and Navy personnel to participate, as well as Army personnel from Fort McClellan.

A means of obtaining the services of two FIDAL specialists from AGAVENCO remains to be determined. These two specialists, necessary equipment, and support at Eglin AFB are considered essential for the functioning of this system. AGAVENCO concurs.

Aircraft Time on Location

In regard to time of aircraft on location, a rough estimate has been made for one month each for the C-123 and FIDAL; two weeks will suffice for the HIDAL. However, it is hoped that any two systems could be on location concurrently. Alternate use would allow a maintenance period every other day for appropriate ground checks prior to a flight. Additionally, feed-back of data of one day's operation would be helpful in scheduling the next configuration. This system of planning, while not extending the over-all time on location for the conduct of all the tests, would require an extension of the time on location for the individual systems. A compromise is suggested of 45 days for the C-123 and the FIDAL, with the C-123 the sole system for the first two weeks and then doubling up with the FIDAL until the C-123 mission is completed. At that time the HIDAL could either be brought in to double up with the FIDAL or the FIDAL could be run singly and the HIDAL last by itself.

Approximate scheduling suggested is shown below:

Day 1 - 15	C-123/MC-1
Day 16 - 45	C-123/MC-1 and FIDAL
Day 46 - 60	FIDAL
Day 61 - 75	HIDAL

Sequence of Operation

The following general sequence of operation will be executed:

1. Configuration selection.
2. Ground checks on performance and readiness (Field 2).
3. Flights (Range 52 S).
4. Laboratory processing (Field 2).
5. Data processing (Field 2).
6. Information feed-back for configuration selection.

Normally, Items 1 and 2 will be performed the day preceding flights. Three hours' air time on a mission is anticipated on the average. Item 4 is likely to require a major portion of a day, so that Item 5 will proceed concurrently with availability of Item 4 findings in order to expedite Item 6.

It is anticipated that the air, meteorological, and field crews will start their day at about dawn minus 2 hours to be on location at first light, the laboratory and data-processing crews to be ready for work at about 0700 or sooner as may be required. The aircraft is expected to arrive at Field 2 after a mission between 0700 and 0800 for maintenance, refueling, and ground checks with the system. The ground check crew would be required on location when the system is available after a mission.

As required, certain personnel may have to be assigned to tasks temporarily where the need is greatest.

Unless directed otherwise, it is considered that the C-123/MC-1 system will be the initial system to be tested, the FIDAL second, and the HIDAL third. It is believed that with this sequence a shakedown period will be minimized.

Indoctrination

It is considered desirable that pilots assigned to this mission be designated on or about 1 April so that they can be assembled and briefed. The success of the mission will depend greatly on their understanding, cooperation, motivation, and performance.

It has been suggested that appropriate service personnel be assigned for familiarization training with the FI24L. It has been tentatively indicated by ARPA that, owing to many factors, Air Force personnel may be designated. [illegible] specialists can conduct this indoctrination while at Eglin AFB.

Indoctrination of the meteorological, air, ground check, field, laboratory, and data-processing crews will be conducted by the respective chiefs-of-crew. An appreciation of the over-all mission should be given to each section, as well as the tasks of the separate units.

APPENDIX F

METHODS AND TECHNIQUES

I. FLOW RATE CALIBRATION ON THE GROUND*

A. C-123/MC-1

Each of the configurations of the C-123/MC-1 system tested over the grid area was calibrated on the ground at the Field 2 site. The C-123 was parked on the remote edge of the concrete pad in front of the control tower with the tail overhanging a sandy strip so that any spilled material would drain away from the pad. Aluminum troughs, or "Purple Catchers," fabricated at Olmsted AFB, were hung on the wing and tail booms with downspouts leading into open-top 55-gallon drums so that the material spraying out of the nozzles was caught in the Purple Catchers and collected in the drums. The level of material in the drums was measured with a calibrated dipstick.

The ground flow check procedure consisted of setting up the nozzle configuration to be checked and functioning the system until the pumps were primed and the booms filled. After the initial levels of liquid in the drums were measured, the system was operated for a measured length of time, usually 15 or 20 seconds, with the pump pressures and rpm's prior to and during spray recorded as well as the indicated flow rate (used from flow meters). Following cessation of spray, the levels of material in the drums and the material temperature were recorded. The measured flow rate was calculated and compared with the flow rate indicated by the system flow meter.

Throughout the calibrations the flow meter readings were in close agreement with the measured flow rate. In consideration of the possible error inherent in the measuring system (the dipstick reading had an accuracy of not better than plus or minus one-half gallon, and 16 to 18 readings were required for each calibration) and the magnification of this error incurred by not being able to spray for more than 20 seconds (because of limited drum capacity), the flow meter reading was adopted as the calibrated value. The pump pressure prior to spraying seemed to be the best value to specify for spray runs.

Since the ground flow checks were conducted during the day, the liquid temperature during the morning spray runs was usually from eight to twelve degrees Centigrade lower than that at which the liquid was calibrated.

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* Prepared by Mr. Paul E. Wampner.

Accordingly, the flow meter indicated a decrease of between ten and twenty gallons per minute during the spray runs from the value obtained during ground flow checks.

Difficulty was experienced early in the spray tests in getting the check valves to reseat after spraying. Initially, this was mainly due to the spring-loaded plug cocking and not returning completely forward upon the release of pressure in the booms. Also, the rubber diaphragms were being distorted with the rapid displacement of the plug by the initial fluid surge. A change from 3-inch booms to booms of 1½-inch diameter eliminated most of the fluid surge and corrected this problem. All subsequent leaking problems were due to foreign particles catching in the check valves. The use of a strainer in filling operations proved partially successful in eliminating such particles, but particles already in the tanks continued to cause some difficulty.

A tendency of the pumps in the MC-1 system to lose prime on standing and then to develop an air block on restart was corrected by the insertion of a bleed line between the top of the pump casing and the tank.

B. HIDAL

Each of the nozzle/liquid configurations for the HIDAL system that were tested over the grid area was calibrated on the ground at the Field 2 site. Aluminum vee-shaped troughs, fabricated at Eglin AFB, were hung from each boom and drained into upright halves of 55-gallon drums so that the material sprayed from the nozzles was caught in the troughs and collected in the half-drums. The levels of material in the drums were measured with a calibrated dipstick.

The ground flow check procedure for the HIDAL started with the system being operated for two to three seconds to fill the booms completely. The initial level of the liquid in the drums was measured and the system was operated for a measured length of time, usually 30 seconds, during which the pump pressure was noted. After a sufficient interval to allow the troughs to drain, the new liquid level was measured and the temperature of the liquid taken. The flow rate was calculated from the amount of liquid sprayed over the measured time interval. It was observed that enough heat was transferred to the liquid by spraying out and pumping back into the HIDAL to raise the temperature of a given liquid about 1°C per trial but no measurable change in pressure or flow rate could be observed over about a 10°C span, which was attributed to the use of a positive displacement pump in the system.

During some of the ground flow checks an extra pressure gauge was installed in one of the inner nozzle connections because the pressure gauge mounted on the pump was affected by vibration and showed needle deflections of as much as eight psi. The boom pressure gauge showed a drop of three psi from the pump through the hose connections and was unaffected by the pump vibration.

II. LABORATORY METHODS AND PROCEDURES*

A. INTRODUCTION

The laboratory group performed the following tasks during the field trials: (a) weighed predetermined quantities of dye for solution in the various test chemicals, (b) assayed six-inch-square aluminum plates sprayed with dyed materials for mass deposit on all flights, (c) assayed "Kromekote" cards sprayed with dyed materials for mass median diameter on all crosswind flights, (d) converted all raw data from sources (b) and (c) to final graphic and tabular form. This report covers items (a) through (d) in the order given above in descriptive terms and relies upon quantitative terms to clarify the description.

B. DYE

It is important to keep uppermost in mind that the material assayed in the laboratory is the dye and not the agent. From the laboratory point of view the agent is just a carrier for a quantity of dye.

1. Dye Requirement

The dye selected for analysis in the field should exhibit several important qualities. The dye should go into solution easily and exhibit an intense coloration at low concentrations so as not to affect the chemical or physical properties of the agents appreciably. It should be resistant to fading on direct exposure to sunlight and should also have the property of an isolated absorbance peak when analyzed with a spectrophotometer.

2. Dye Selection

Laboratory screening of commercially available dyes indicated that Du Pont Oil Red Dye was acceptable for use. A quantity of dye equal to 0.1 per cent by weight of Purple gave intense coloration and an absorbance peak at 515 millimicrons on a spectrophotometer. Additionally, this quantity of dye allowed the spectrophotometer to be calibrated from 0.1 gallon to 10.0 gallons per acre and could be extended on the higher deposit end of the curve if necessary.

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* Prepared by George W. Trout, Jr.

3. Dye Quantity

The same quantity of dye (0.1 per cent by weight of Purple) was added to all spray solutions (Purple, No. 2 diesel fuel oil, and a mixture of two parts No. 2 diesel fuel oil and one part Purple) in order to yield the identical calibration curve. This then gave a solution 0.144 per cent by weight in the fuel oil and 0.126 per cent in the 2:1 mix. In the field a known quantity of dyed material was placed on an aluminum plate and exposed to direct midday sunlight for 15 minutes. No fading of the dye was noticed when it was assayed in a spectrophotometer and compared with a control plate that was kept in darkness.

4. Mixing

In the field laboratory 245 grams (0.54 pound) of the dye were weighed in one-quart cardboard containers. This quantity of dye was added to a 50-gallon drum of chemical material (Purple or fuel oil). The drum was then replugged, laid on its side and rolled on the runway to insure mixing of the dye. The drum was righted, opened, and the material was pumped into the tank or tanks of the aircraft.

5. Samples

Prior to flying the test aircraft a sample of the dyed material was withdrawn from the tank or tanks of the aircraft for use in calibrating the spectrophotometer. This sample was always drawn immediately prior to take-off for the grid and represented a composite of all the drums of material pumped into the aircraft. A second sample was drawn from the aircraft after the spray mission was completed and the plane returned from the grid. Hence in all cases at least two samples of the spray material were taken from the aircraft.

These samples when properly diluted yielded a calibration curve for the day, which was used to determine mass deposit at the sampling stations.

6. Calibration

The following calculations illustrate the calibration technique:

1 acre contains 43,560 square feet
1 six-inch-square aluminum plate contains ¼ square foot
174,240 plates are required to cover one acre
1 gallon contains 3,785.3 milliliters

Therefore a deposition of one gallon per acre is represented by 3,785.3 ml/174,240 = 0.0217 milliliter of dyed material per plate. Hence,

10 gpa = 0.217 ml/plate
8 gpa = 0.174 ml/plate
6 gpa = 0.130 ml/plate
0.1 gpa = 0.00217 ml/plate, etc.

This quantity of material dissolved in any volume of solvent represents the calibration curve.

To calibrate, 2.17 ml of the sample was diluted to 50 ml with acetone. Five ml of this dilution was further diluted to 25 ml with acetone, to give a 10-gpa deposit rate. To illustrate the daily calibration technique, 2.17 ml of the sample diluted to 50 ml corresponds to 50 gpa. Thereafter:

Amount of First Dilution, ml	Deposition Rate, gpa
5.0	10
4.5	9
4.0	8
3.5	7
3.0	6
2.5	5
2.0	4
1.5	3
1.0	2
0.5	1

In each case the per cent transmission of the dilution was read and recorded. The logarithm of the per cent transmission plotted against deposition rate gave the daily calibration curve. Figure 1 shows a typical calibration curve. It should be noted that the curve passes through 100 per cent transmission for 0.0 gpa. This is logical because the 100 per cent figure is based on an acetone blank. The linearity of the line makes reading of the curve a very simple matter.

B. MASS DEPOSIT

After a plate was sprayed in the field it was covered with a clean plate to form a sandwich, trapping the dyed material between the two plates. These were then placed in a light-proof box and returned to the laboratory. In the laboratory the plate and its cover were placed on a special rack above a glass fan-shaped funnel, a standard laboratory funnel, and a 25-ml volumetric flask. This arrangement allowed both plates to be washed into a single flask. Figure 2 shows the arrangement of the plate-washing apparatus.

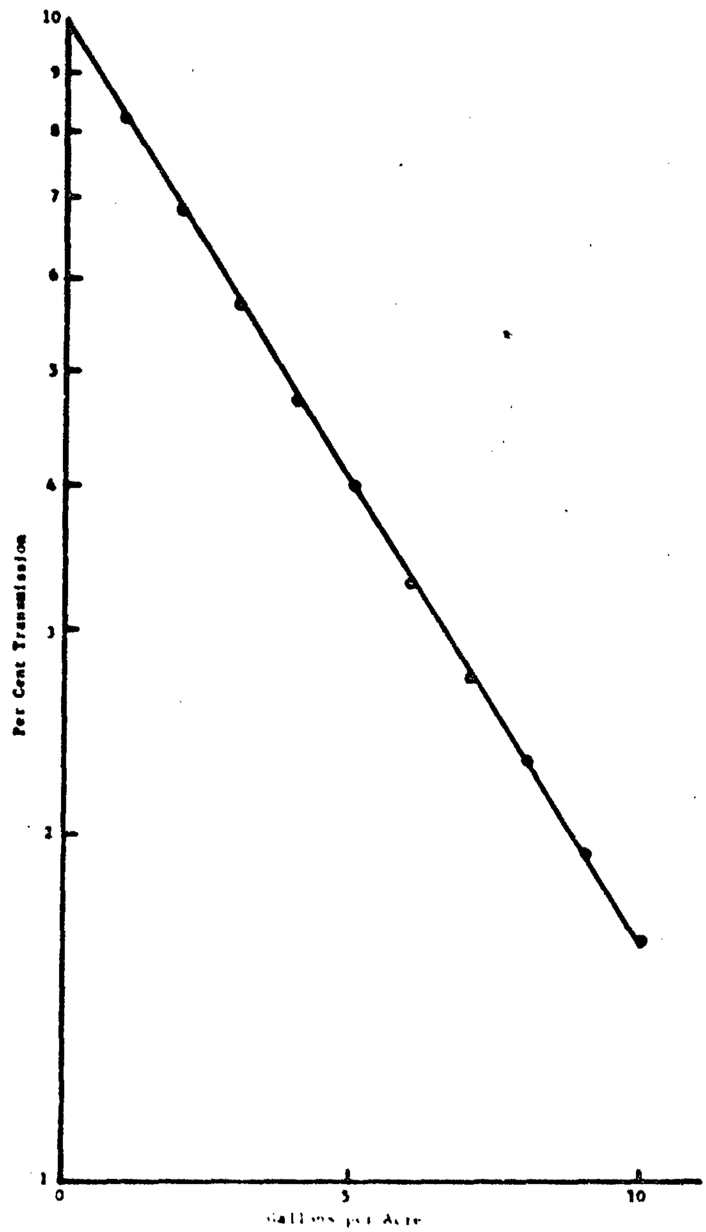

Figure 1. Typical Calibration Curve.

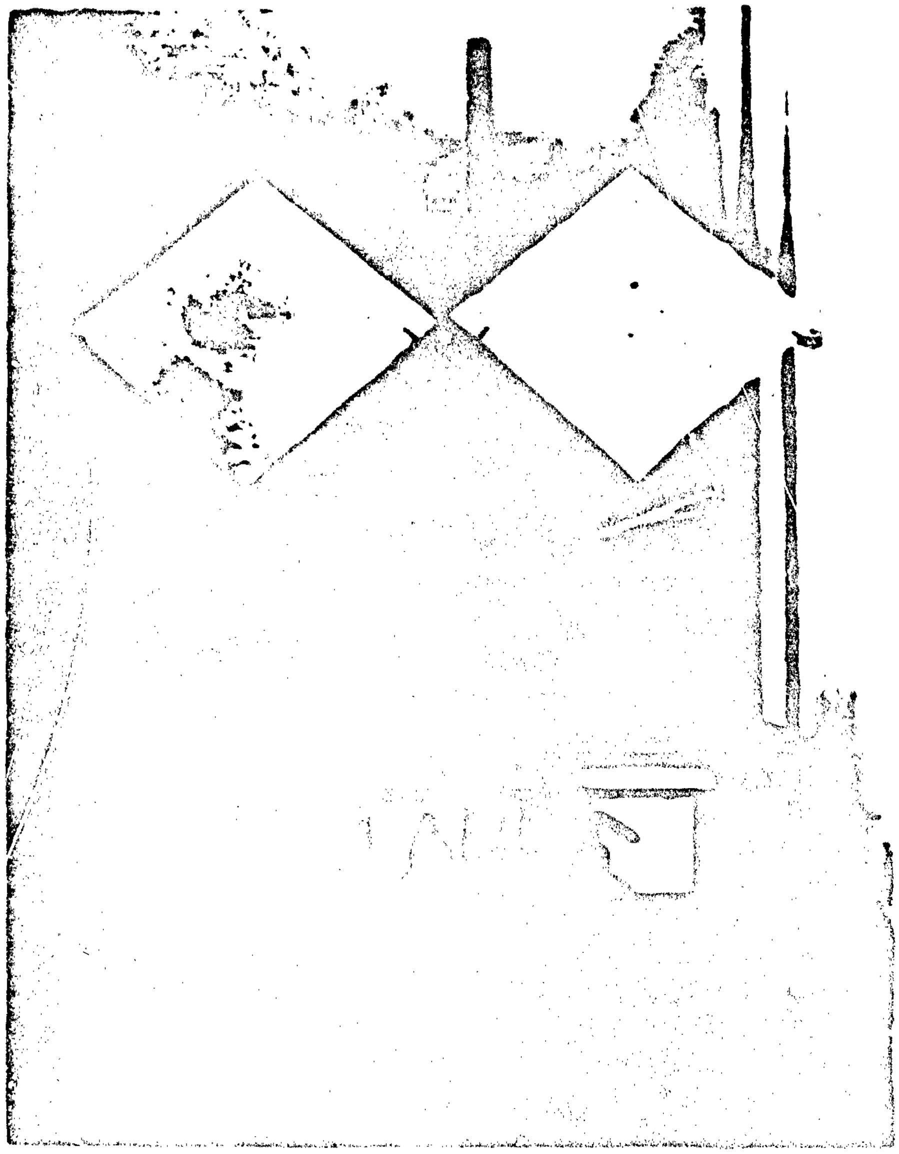

Figure 2. Rack for Washing Spray Deposit from Metal Plates.
(U.S. Air Force Photo)

A member of the laboratory crew washed the two plates with acetone through a spray nozzle, working from the upper corner of the plate down toward the lower corner. The dyed material plus acetone solvent was collected through the two funnels and into the flask.

Originally, filter paper was used in the second funnel to remove dust and dirt that may have collected on the plate. This practice was discontinued when it was shown that the filter paper removed a significant portion of the dye.

After the plates were spray-washed the funnels were washed with acetone from the spray system and all the liquid was collected in the flask. The volume of the flask was then brought to 25 ml with a laboratory plastic wash bottle and the diluted samples were placed in light-proof boxes and taken to the spectrophotometer for analysis.

Another member of the laboratory crew carefully shook the contents of the flask, rinsed a spectrophotometer cuvette with a portion of the sample, and then filled the cuvette with the sample. The per cent transmission of the sample was compared with that of an acetone blank. Duplicate measurements were taken from each sample to insure against errors in reading the scale of the spectrophotometer. When necessary three or more readings were taken.

The transmission figures were recorded on prepared forms. A data technician used the calibration curve of the day to convert per cent transmission to mass deposit. Rates were plotted on a specially prepared graph that represented the mass deposit at any station and gave visually the swath width at any desired deposit level.

C. MASS MEDIAN DIAMETER

Adjacent to each aluminum plate placed in the field was a similar plate with a "Kromekote" card clipped to it. These plates were collected at the end of a flight, along with the sample plates, and were placed in a specially prepared box.

The cards served a dual purpose: (a) on inwind flights they indicated which plates had received spray deposit, and (b) on crosswind flights they were used to estimate MMD.

The technique of using these cards for MMD estimates was identical to that used in the June - July 1962 field test.*

Since the previous field test was conducted, considerable investigation has been performed by Physical Sciences Division Fort Detrick, to correlate more accurately the spherical drop size with the spot size on the cards.** It was determined that with the agent tested a linear relationship existed between spot size and true spherical diameter when the spot diameter was 500 microns to 3600 microns. This range correlated to spherical diameters of 150 to 600 microns, given spread factors ranging from 5.6 to 6.4

Unfortunately, No. 2 diesel fuel oil was not included in the study and a spread factor of 6.0 was assumed for that agent.

With the exception of this one modification to the analysis the technique remained identical to that used in the previous test.

All MMD's were tabulated and the necessary calculations were performed to relate spot size to spherical diameter.

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* Brown, J.W., and Whittam, D. "Modification and Calibration of Defoliation Equipment (C-123 - First Modification)," July 1962.
** U. S. Army Biological Laboratories, Frederick, Maryland, Physical Sciences Division. "Report to Crops Division on Spread Factor Calibration Studies of Eglin A F B Test Agent Samples and O [illegible] Agent Samples," by W.R. Wolf, October 1962.

III. SAMPLING GRID OPERATION

The sampling grid constructed for the spray calibration trials during the summer of 1962 was used for the 1963 trials. Replacement of stakes and plate holders and training of personnel to service the grid were completed within three days after arrival on location.

A grid diagram work sheet (Appendix H) was prepared to facilitate selection by the grid controller of an aircraft course appropriate to the prevailing meteorological conditions. Any unusual occurrences during the grid operation were also noted on the work sheet.

Two jeeps with three men each were used to service the sample line. One jeep and crew would service Stations 1 through 50 and the other crew Stations 51 through 100. The three-man crew consisted of (a) a driver-radio operator, (b) a pick-up and placement man, and (c) a man to receive exposed plates and cards and place these in proper sequence in containers. Information was radioed to the jeep crews as to which sample line was to be used.

The two jeeps and crews were dispatched to the hub of the grid, at which point they would receive their instructions regarding sample line selection. Upon receiving this information, they would place on each stake two serially numbered clean six-inch-square aluminum plates. A four- by five-inch white Kromekote card was clipped to one of these plates. After setting up a line the crews would remain off the extreme ends of the sample line until after the spray flight and a subsequent ten-minute period for the spray to settle. The crews were told by radio when to collect the sample cards and plates.

Plates with the Kromekote cards were placed in an open-top box with slots that prevented them from touching each other. These cards were used to obtain a visual record of deposit of the spray and the prevailing array of droplet sizes. The aluminum plate that was exposed to the chemical was covered with an unexposed plate of the same size and these were stacked in a light-tight box.

The number of plates being handled made it impossible for the crew to reset the sample line as they moved toward the hub during the pick-up operation. Therefore, they were instructed after they had reached the hub of the grid as to which line would be set up for the next flight.

A third jeep was used as runner to keep fresh plates supplied to the two jeeps serving the sample lines and to return exposed plates to the truck.

A ground-to-air radio (UHF) was on location for communication with the aircraft. Once the sample line was set up the aircraft course, airspeed, and altitude for the next flight were radioed to the pilot.

Meteorological information consisted of wind direction, wind speed, dry and wet bulb temperatures, and relative humidity. These readings were made at 50-foot intervals from surface to 200-foot altitude when the C-123/MC-1 system was being calibrated. Readings at 25-foot intervals were made up to 100 feet when the H-34/HIDAL system was being calibrated.

Four tethered Jalbert J-5 balloons (Figures 3 and 4) were used in obtaining the above meteorological information. One of the balloons was placed approximately 100 feet out from the ends of each sample line B, D, and D'. The fourth balloon was located at the CP (control point), which was approximately 1000 feet from the last station on sample line D'.

The meteorological personnel were from the 6th Weather Squadron, Tinker AFB, Oklahoma, and were supervised by personnel from Detachment 6, Weather Group, Eglin AFB, Florida.

Meteorological personnel reported to the grid at 0030 hours to set up equipment and make meteorological observations to determine if the weather would be suitable for operation each morning. When the weather was adverse, the Project Officer was notified and the trial was cancelled prior to 0300 hours. After this time it was impossible to alert all personnel who were assigned grid duties because many were already enroute to their stations. The decision to proceed with the mission or to abort was then made at the grid as the meteorological situation improved or deteriorated.

The four meteorological stations communicated with one another by field phones. All stations reported the meteorological information to a central recorder located at the CP. The data were recorded on a form (Appendix H) that was turned over to the grid controller for use in determining the aircraft course for the next flight and for a record of the meteorological data at the time of spray release.

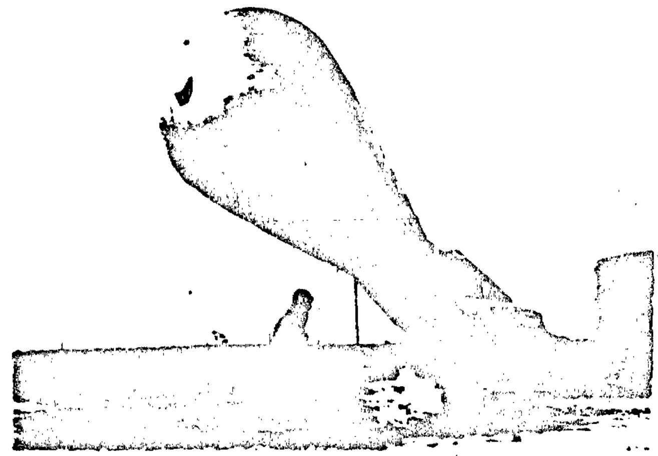

Figure 3. Balloon Used in Obtaining Meteorological Data. (U.S. Air Force Photo)

Figure 4. Balloon Used in Obtaining Meteorological Data. (U.S. Air Force Photo)

Eglin AFB Agent Samples: July 1962

STAINED CARD SPOT SIZE, SPREAD FACTOR, SPHERICAL DROP DIAMETER, MASS MEDIAN DIAMETER

Material: Purple

(Data courtesy Mr. Walton Wolf, Physical Sciences Division, September 1962)

Stained Card Spot Size, microns	Spread Factor	Spherical Drop Diameter, microns	Mass Median Diameter	
			Low Speed (C.F. = 2.2)	High Speed (C.F. = 2.5)
2000	5.408	356.6	162.1	142.6
2100	5.660	371.0	168.6	148.4
2200	5.710	385.3	175.1	154.1
2300	5.756	399.6	181.6	159.8
2400	5.798	413.9	188.1	165.6
2500	5.838	428.2	194.6	171.3
2600	5.876	442.5	201.1	177.0
2700	5.911	456.8	207.6	182.7
2800	5.944	471.1	214.1	188.4
2900	5.974	485.4	220.6	194.2
3000	6.004	499.7	227.1	199.9
3100	6.031	514.0	233.6	205.6
3200	6.055	528.4	240.2	211.4
3300	6.081	542.7	246.7	217.1
3400	6.104	557.0	253.2	222.8
3500	6.126	571.3	259.7	228.5
3600	6.148	585.6	266.2	234.2
3700	6.168	599.9	272.7	240.0
3800	6.187	614.2	279.2	245.7
3900	6.205	628.5	285.7	251.4
4000	6.223	642.8	292.2	257.1
4100	6.238	657.2	298.7	262.9
4200	6.255	671.5	305.2	268.6
4300	6.270	685.8	311.7	274.3
4400	6.285	700.1	318.2	280.0
4500	6.299	714.4	324.7	285.8
4600	6.313	728.7	331.2	291.5
4700	6.326	743.0	337.7	297.2
4800	6.338	757.3	344.2	302.9
4900	6.350	771.6	350.7	308.6
5000	6.362	785.9	357.2	314.4
5100	6.373	800.2	363.7	320.1
5200	6.384	814.5	370.2	325.8
5300	6.395	828.8	376.7	331.5
5400	6.405	843.1	383.2	337.2
5500	6.415	857.4	389.7	343.0
5600	6.424	871.7	396.2	348.7
5700	6.433	886.0	402.7	354.4
5800	6.442	900.3	409.2	360.1
5900	6.451	914.6	415.7	365.8
6000	6.459	929.0	422.2	371.6
6100	6.467	943.3	428.7	377.3
6200	6.475	957.6	435.2	383.0
6300	6.482	971.9	441.7	388.8
6400	6.490	986.2	448.2	394.5
6500	6.497	1000.5	454.7	400.2
6600	6.504	1014.8	461.2	405.9
6700	6.511	1029.1	467.7	411.6
6800	6.517	1043.4	474.2	417.4
6900	6.524	1057.7	480.7	423.1
7000	6.529	1072.1	487.3	428.8

Note: Spherical Diameter = 70.44 + 0.1431 SS.

Eglin AFB Agent Samples: July 1962

STAINED CARD SPOT SIZE, SPREAD FACTOR, SPHERICAL DROP DIAMETER,
MASS MEDIAN DIAMETER

Material: 1 Purple, 2 Fuel Oil Mix (Avg. of Samples "A" and "B")

(Data courtesy Mr. Walton Wolf, Physical Sciences Division, September 1962)

Stained Card Spot Size, microns	Spread Factor	Spherical Drop Diameter, microns	Mass Median Diameter	
			Low Speed (C.F. = 2.2)	High Speed (C.F. = 2.5)
2000	5.687	351.7	159.8	140.7
2100	5.739	365.9	166.3	146.4
2200	5.768	380.1	172.8	152.0
2300	5.833	394.3	179.2	157.7
2400	5.875	408.5	185.7	163.4
2500	5.914	422.7	192.1	169.1
2600	5.951	436.9	198.6	174.8
2700	5.985	451.1	205.0	180.4
2800	6.018	465.3	211.5	186.1
2900	6.048	479.5	217.9	191.8
3000	6.077	493.7	224.4	197.5
3100	6.104	507.[illegible]	230.8	203.2
3200	6.129	522.1	237.3	208.8
3300	6.153	536.3	243.7	214.5
3400	6.177	550.4	250.2	220.2
3500	6.199	564.6	256.6	225.8
3600	6.220	578.8	263.1	231.5
3700	6.239	593.0	269.5	237.2
3800	6.258	607.2	276.4	242.9
3900	6.276	621.4	282.4	248.6
4000	6.293	635.6	288.9	254.2
4100	6.310	649.8	295.3	259.9
4200	6.325	664.0	301.8	265.6
4300	6.340	678.2	308.2	271.[illegible]
4400	6.355	692.4	314.7	277.0
4500	6.369	706.6	321.1	282.6
4600	6.382	720.8	327.6	288.3
4700	6.395	735.0	334.1	294.0
4800	6.407	749.2	340.5	299.7
4900	6.419	763.4	347.0	305.4
5000	6.430	777.6	353.4	311.0
5100	6.441	791.8	359.9	316.7
5200	6.451	806.1	366.[illegible]	322.4
5300	6.461	820.3	372.8	[illegible].1
5400	6.471	834.5	379.3	[illegible].8
5500	6.481	848.7	385.7	[illegible]9.5
5600	6.491	862.9	392.2	345.2
5700	6.499	877.1	398.6	350.8
5800	6.507	991.3	405.1	356.5
5900	6.516	905.5	411.5	362.2
6000	6.524	919.7	418.0	367.9
6100	6.532	933.9	424.4	373.6
6200	6.539	948.1	430.9	379.2
6300	6.547	962.3	437.4	385.9
6400	6.554	976.5	443.8	390.6
6500	6.565	990.7	450.3	396.3
6600	6.568	1004.9	456.7	402.0
6700	6.574	1019.1	463.2	405.6
6800	6.581	1033.3	469.6	411.3
6900	6.587	1047.5	476.1	417.0
7000	6.593	1061.7	482.5	424.7

Note: Spherical Diameter = 67.72 + 0.1420 SS.

APPENDIX C

PERSONNEL OF ARPA CALIBRATION TRIALS, 1963

Eglin Air Force Base, Florida

U.S. Army Biological Laboratories, Fort Detrick, Maryland

Crops Division
- Mr. Lester W. Boyer
- Mr. Raymond W. Anders
- Mr. Earl W. Bere
- Lt. Albert L. Bertram
- Pvt. Walter J. Hart
- Pvt. Glen E. Trumble

Office, Director of Biological Research
- Maj. Alvin R. Hylton

Physical Sciences Division
- Mr. George W. Trout, Jr.
- Sp-4 Robert Boulster
- Sp-4 Austin W. Hogan

Technical Evaluation Division
- Mr. Donald Rice
- Mr. Kenneth Plumby
- Mr. Kenneth Lewis
- Mr. Kenneth Marsh
- Mr. Charles A. Staley

Technical Information Division
- Mr. Paul Riley
- Mr. Alan Cissna

Munitions Development Division
- Mr. Paul E. Wampner
- Pfc. Samuel J. Cannella

Maintenance Division
- Mr. Kenneth Krantz

Detailed from other Divisions
- Pfc. Lawrence M. Giacomini
- Sp-4 James McClure
- Pfc. Jay M. Wiegner
- Sp-5 Bernard A. Latakas
- Sp-5 James A. Hightower

U. S. Army Chemical Corps, Fort McClellan, Alabama

18th Chemical Detachment (TI)
- Lt. John B. Byrd
- S/Sgt Stanley J. Kostszycki
- Sp-5 Thomas F. Hoffman
- Sp-5 Ira [illegible]. Collins
- Pfc. Joseph [illegible]. Molesky

69th Chemical Company (SG)
- Sp-4 Robert A. O'Conner
- Pfc. Franklin D. Belcher
- Pfc. Clair N. Carley
- Pfc. Donald H. Lyons
- Pfc. Cecil E. McElfresh
- Pfc. Joseph J. Techacek

MAAMA, Olmsted AFB, Pennsylvania
- Mr. Kenneth Baird
- Mr. Allen R. Kaylor

Eglin AFB, Florida
- Lt. Vernon L. Hazen
- Lt. A Krantz
- Mrs Caroline Gregg

4500th Operations Squadron, Langley AFB, Virginia
- Captain Carl W. Marshall
- Captain Hugh C. Shirley
- Captain Larry R. Youngren
- Captain Paul A. [illegible]ehmer, Jr.
- Captain George [illegible] Adams
- [illegible] Richard G. [illegible]
- S/Sgt Earle H. [illegible], Jr
- S/Sgt John A. Melsi.
- S/Sgt Keith D. [illegible]
- S/Sgt Richard A. Nelson
- S/Sgt Reginald I. Nelson
- A/[illegible] Lloyd H. Ramsey
- A/2 Steven A. Lowe

U. S. Army Chemical Corps, Edgewood, Maryland
- WO Wilbur M. Isenberg

Naval Air Station, Jacksonville, Florida
- Mr. [illegible] Hayden
- Mr. [illegible] Branson
- Captain George S. Stains, OIC, [illegible]

APPENDIX H

SAMPLE WORK FORMS

MASS MEDIAN DIAMETER

Date ____________

Flight No. ____________

Sample Line ____________

Flow Rate ____________

St	Drop #	Size

Spread Factor ____________

Conversion Factor ____________

Paper ____________

Material ____________

System ____________

St	Drop #	Size

$$\text{MMD} = \frac{\text{Spot D Max}}{\text{Spread Factor x Con. Factor}} =$$

Max. Spherical Diameter =

Min. Spherical Diameter =

MASS DEPOSIT

Material __________ Airspeed __________
Date __________ Altitude __________
Flight __________ Swath Width __________
Sample Line __________ Aircraft Course __________
Time of Release __________ Wind Vector __________
Duration __________ Spec. __________
Flow Rate __________ Spec. Oper. __________
System __________

St	GPA	St	GPA	St	GPA	St	GPA
1		26		51		76	
2		27		52		77	
3		28		53		78	
4		29		54		79	
5		30		55		80	
6		31		56		81	
7		32		57		82	
8		33		58		83	
9		34		59		84	
10		35		60		85	
11		36		61		86	
12		37		62		87	
13		38		63		88	
14		39		64		89	
15		40		65		90	
16		41		66		91	
17		42		67		92	
18		43		68		93	
19		44		69		94	
20		45		70		95	
21		46		71		96	
22		47		72		97	
23		48		73		98	
24		49		74		99	
25		50		75		100	

Total Deposit=
Percent Recovery=

SMUFD FORM 547 (Temp)
(9 April 1963)

RAW DATA SHEET

Date ______________ Spec. ______________

Material ______________ Spec. Oper. ______________

Flight ______________ Standard ______________

Sample Line ______________ Fade Loss ______________

Sta	% Transmittance			Avg	Sta	% Transmittance			Avg	Sta	% Transmittance			Avg
1					34					67				
2					35					68				
3					36					69				
4					37					70				
5					38					71				
6					39					72				
7					40					73				
8					41					74				
9					42					75				
10					43					76				
11					44					77				
12					45					78				
13					46					79				
14					47					80				
15					48					81				
16					49					82				
17					50					83				
18					51					84				
19					52					85				
20					53					86				
21					54					87				
22					55					88				
23					56					89				
24					57					90				
25					58					91				
26					59					92				
27					60					93				
28					61					94				
29					62					95				
30					63					96				
31					64					97				
32					65					98				
[illegible]					66					99				
I P										100				

SMFD Form 54 (Temp) (9 Apr 63)